PRELIMINARY REPORT TO THE

# ILLINOIS STATE BOARD OF HEALTH.

# WATER SUPPLIES OF ILLINOIS

AND THE

# POLLUTION OF ITS STREAMS.



BY JOHN H. RAUCH, M. D., *Secretary.*

WITH TWO APPENDICES:

*I.—Chemical Investigations of the Water Supplies of Illinois. By Prof. J. H. Long.*

*II.—The Illinois River Basin in Its Relations to Sanitary Engineering. By L. E. Cooley, C. E.*



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# NOTE.—Explanatory and Supplemental.

In order to meet the inquiries of members of the present General Assembly for information concerning certain subjects of pending legislation, the State Board of Health has authorized the preparation of the following preliminary report on the Water Supplies of Illinois and the Pollution of its Streams- The matter has been necessarily prepared hastily—*only ten days having elapsed since the results of the last chemical investigations were received in the Secretary's office.* This hurried preparation will also account for the incomplete appearance of the document, It is believed, however, that enough is furnished to give a good general idea of the character and scope of the work, to foreshadow the results of the completed report, and to determine with substantial accuracy some of the most important questions involved in the bill for an act to create sanitary districts in Illinois.

It will be seen from the following pages that the opinions of the Secretary, formulated more than ten years ago, concerning the essential sanitary interests of the communities in the Desplaines and Illinois valleys, have undergone no material modification, but are substantially corroborated by these subsequent investigations and study. For the remedy of the nuisance created by the drainage of Chicago into the Illinois and Michigan Canal and the Illinois river, it is demonstrated that the minimum quantity of water pumped at Bridgeport heretofore recommended is absolutely necessary. That quantity was fixed by the Secretary in 1879 at 60,000 cubic feet per minute when the population draining into the river was less than 400,000.

Subsequently it has taken the form of a general statement—frequently repeated in reports to the Board—that the sanitary interests of the communities in the Desplaines and Illinois valleys demand that the sewage of Chicago pumped into the canal shall be diluted on the scale of 14,000 cubic feet per minute for every 100,000 inhabitants as a minimum. In winter, when oxidation is retarded by ice formation shutting out light and air, by low temperature and by impeded motion, a greater rather than a lesser quantity should be pumped. The recent analyses fully sustain this dictum.

As a matter of fact the average quantity pumped during the period covered by these investigations did not exceed 45,000 cubic feet during the summer of 1888, and not more than 38.000 cubic feet during the last winter. This quantity is less than one-half the minimum dilution necessary to prevent nuisance at Joliet.

The city of Chicago should be required to increase the capacity of the pumping plant at Bridgeport to 100,000 cubic feet at once. With a comparatively small outlay—say $10,000—the canal can be made to carry this quantity readily although it is probable that one or two bridges would require to be raised somewhat.

For further relief pumps should be erected at some suitable point of discharge into the Desplaines river, and these should be of the capacity recommended in 1879, to-wit: 50,000 cubic feet per minute. If such discharge into the Desplaines be secured promptly then a lesser quantity may be pumped into the canal and the necessity of raising the bridges would be obviated. But with the sewage of over 800,000 inhabitants already tributary to the canal the minimum dilution above specified requires at the present time that at least 112,000 cubic feet per minute be pumped into these channels. This quantity may readily be drawn through the south branch without creating too great a current; but it may be necessasy to provide some other source of supply from Lake

Michigan for the maximum quantity of 250,000 cubic feet which will be required for population before the close of the century on the most conservative estimate of grov

Even if the project for a great waterway from Lake Michigan to the Illinois river w under way to-day, such additional pumping will be needed before the work coul completed and made available for this relief of the communities in the lower valley relief which is now imperatively demanded as a sanitary necessity.

While these sheets are in the printer's hands, a report on the sewage of the My and Charles river valleys is received. This was prepared in accordance with insti tions from the General Court by the State Board of Health of Massachusetts and, v its appended documents and maps, forms a volume of 138 octavo pages. Plans estimates were made for each of the three principal methods of sewage disposal, to- (1) Discharge of the crude sewage into the outgoing tidal currents; (2) partial puri tion by intermittent filtration; (3) chemical precipitation and discharge of effluent the tide during first ebb. The plans and estimates for each method were prepared engineers specially qualified in the respective methods. Upon review of the plans the chief engineer of the Board and an associate consulting engineer, the first met —that of discharge of the crude sewage upon the first of the ebb tide, a method ess tially the same as that of discharge into a non-tidal river of sufficient volume— selected and approved.

This result is in substantial accord with the considerations set forth in the follow pages as to the relative practicability of the three methods. The territory covered the report includes an area of 130 square miles surrounding Boston on the north, so and west, and having a population of less than 150,000. The cost of the investigati and report was $25,000. The Preliminary Report of the Drainage and Water Su Commission of the City of Chicago, published in January, 1887, also covered th methods, to-wit: (1) Discharge of the crude sewage into Lake Michigan; (2) disposal land by intermittent filtration; (3) discharge into the Desplaines river. Plans and e mates for the first two methods were prepared in sufficient detail to demonstrate th impracticability.

The discharge into Lake Michigan would involve an expenditure of at least $37,000 and an annual expense of over $2,400,000 for interest and maintenance. Aside from cost the Commission rejected this method because, while it might be practicable some years to allow the sewage in its crude form to enter the lake under the conditi prescribed, the necessity would sooner or later arise for clarifying it previous to discharge. The experience of London and other large cities does not warrant adoption of a plan involving such a contingency.

As to the second method—that of disposal by land—it is apparent from the tenor the report that the Commission was strongly predisposed in its favor, and only ab doned it when it became obvious that suitable land in sufficient quantity was not av able within the borders of the State at any practicable distance. Given a suitable bo of land the plans of the Commission for the disposal of the metropolitan sewage alc by intermittent filtration and sewage farming, would require an investment of ab $58,000,000, with an annual expense of over $3,000,000 for interest, pumping and mair nance after deducting the profit from sale of crops. The disposal of the sewage of Calumet region would add about $4,000,000 to the cost of this plan, or a total of $62,0 000.

Compelled to the rejection of both these plans the Commission next took up third solution of the drainage problem on the lines recognized by that distinguis engineer, Mr. E. S. Chesbrough, as early as 1856, and fully outlined in the extracts— printed in the following pages—from a report to the Illinois State Board of Health the "Sanitary Problems of Chicago" made by the Secretary in 1879.* This solution c sists, in brief, of such modification of the conditions which have existed since 18 when the "deep cut" in the Illinois and Michigan Canal was completed—as shall sec

*See page IV et seq., of the Preliminary Report which follows.

a flow of water from Lake Michigan into the Illinois river ample at all times to dilute the sewage beyond the point of offensiveness to the senses or injury to health. As shown on p. 65 of the appendix to this Preliminary Report,† there was in 1888 a population of 842,300 inhabitants, the sewage of which, so far as it is disposed of at all, is discharged into the Illinois and Michigan canal by the pumps at Bridgeport. For present practical purposes the aggregate water supply may be assumed as the measure of the sewage product—any material variation, either as to volume or density, being compensated for by the storm-water discharge and its incident pollution, the character of wastes from stock yards, slaughter houses, etc.,—so that it will not be far out of the way to state the daily sewage product now tributary to the canal at 150,000,000 gallons per day. During the summer of 1888, as already stated, the Bridgeport pumps discharged into the canal 45,000 cubic feet per minute, or 485,280,000 gallons per day. Roughly stated, this was composed of one part of sewage and two parts of lake water, During the winter the proportion of sewage was somewhat greater, in the ratio of 45,000 to 38,000—the number of cubic feet pumped in the summer and the winter respectively.

The Commission finally approved of the project for the construction of an artificial waterway capable of carrying 600,000 cubic feet per minute, through the Chicago river and the necessary conduits, from Lake Michigan to Lake Joliet. This quantity of water per minute represents 6,480,000,000 gallons per day. If we admit that the ultimate population in the area to be drained will reach 2,500,000, and that its average sewage product (150 gallons per head) will amount to 375,000,000 gallons per day, this quantity—6,480,000,000 gallons—would give a fraction over 17 dilutions, or more than sixteen parts of lake water to one of sewage, instead of two parts lake water to one of sewage as now. It is to be noted that this would be the minimum dilution, and not likely to be reached until sometime between 1910 and 1915.

From four different sets of observations—made in the summer of 1886, in the winter of 1886-7, in the summer of 1888, and in January, February and March, 1889*—there is no hesitation in saying that even this minimum dilution, for the maximum population which we are warranted in considering attainable, would suffice to prevent any nuisance from Chicago sewage long before it reached Lockport, and that the sanitary condition of the Desplaines and Illinois rivers would be greatly benefitted in every respect. The large amount of dissolved oxygen in the lake water and its freedom from organic impurity would not only hasten the decomposition of the sewage—resolving it into its harmless inorganic elements—but in the volume proposed it would assist in the oxidation of the sewage from the river towns, as well as of the large amount of organic matter of vegetable origin contributed to the Illinois by many of its tributaries. For further details in this connection the reader is referred to the report proper and to the two appendices.

Among other points clearly indicated by the chemical analyses and sanitary investigations is the necessity of continuous observations of the water supplies of cities, towns and villages and of the State institutions throughout a long period. It cannot be too strongly urged that these observations should be of a general sanitary character, embracing the source and history of the water, its observed effects upon health, etc. It will not do to place reliance solely upon the answers to reagents and tests in the chemist's laboratory. These, unless taken in connection with all the surroundings, may be very misleading. Water analysis has undergone a radical change within the past few years. Even so late as 1881, examinations of water by three separate processes, each of which had its pronounced supporters, gave the most confounding results. Of 19 waters, known by long experience to be productive of no harmful effects and regarded as wholesome, only 5 were pronounced "good" by all the processes; 8 others of this class were pronounced "good" by some, and "fair," "medium," or "allowable" by the others; 3 were accounted "bad" by one process, 1 by two processes, and two by all of the processes. Of twenty waters of more or less doubtful or suspected character, 9 were reported "good" or "allowable" by all the methods, 5 "bad" by one, 3 by two, and 3 others by all.

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†The Illinois River Basin in its Relations to Sanitary Engineering. By L. E. Cooley, C. E.

*See pages XXVII-XXX of the following report.

Of 3[illegible] waters which were believed on strong grounds to have produced disease amon those drinking them, 10 were pronounced "good" or "allowable" by all the processes, "bad" by one process, 1 by two and only 3 by all. As Prof. J. W. Mallett, F. R. S., wh conducted this examination for the National Board of Health, says in his report: I is not possible to decide absolutely upon the wholesomeness or unwholesomeness of drinking-water by the mere use of any of the processes examined for the estimation organic matter or its constituents. It will not do merely to throw all doubts on the sid of the rejection of a water as has been more or less advocated by writers on wate analysis; for there are often interests of too serious character involved in such rejectio to admit of its being decided on, save upon really convincing evidence of its necessit

The analysis is essential, but may be accepted as conclusive only when supplemente by the revelations of the microscope in biological investigation and illuminated by th knowledge to be furnished by a sanitary survey and the practical tests of sickness an death rate. Only by continuous observation and frequent analyses, corrected by th work of the sanitary inspector, will communities take the steps necessary to secure a wholesome water supply and to preserve its sources from pollution. It is purposed t maintain this surveillance over the water supplies of the State institutions, and in the the records of sickness and mortality, which may be obtained with greater certainty and completeness than in communities, will afford a practical test of the value of su surveillance.

The immediately preceding observations borrow increased significance from the text of the last few pages of the report proper. In illustrating the generalization tha "the aggregate of organic matter furnished by the tributaries of the Illinois river in their natural condition may greatly exceed the aggregate furnished by the populatio of their respective watersheds or than the aggregate which passes Joliet in the cana and Desplaines river," it is not made sufficiently clear that the standard of wholesomeness or unwholesomeness of a water may not be fixed solely by the results of the chemica determinations. The nature and source of the organic matter contained must be take into account, and the neglect to do this may be unintentionally, but, nevertheless, quite seriously misleading. This is now seen to be the case with the illustration noted—pages xxx, xxxiii. In the final report, when all the data shall have been considered and eac factor be given its due weight, the general tenor would suffice to prevent any misinterpretation of such a passage.

Sundry typographical errors, incident to the haste with which these pages have bee prepared and put through the press, will not escape the notice of even the least critical. Fortunately these are of minor importance and do not affect the general accuracy nor impair argument or conclusion.—April 3, 1889.—J. H. R.

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Due acknowledgement will be made in the completed report to a number of volunteers who have greatly assisted in the work by observations and in other ways.

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With increasing density of population, and more particularly with continuous occupancy of soil, certain questions intimately connected with the problem of healthy living press upon the general attention and impose additional responsibility upon those charged with the protection of the public health. By the act of the General Assembly creating a State Board of Health for the State of Illinois, this Board is entrusted with the "general supervision of the life and health of the citizens of the State." It is charged with the responsibility and endowed with "authority to make such sanitary investigations as it may, from time to time, deem necessary for the preservation or improvement of the public health."

Under this authority and in the discharge of this duty, the sanitary investigation of the water supplies of the State, and the study of the sources, extent and means of remedy of the pollution of its rivers and streams, have been pushed during the past twelve months with more vigor and on a much broader scale than have been heretofore practicable with the means at its command.

This investigation and study were among the earliest efforts of the Board, although they were at first necessarily confined to pressing emergencies; and it will be useful to give a resumé of the report of the Secretary on this subject made to the Board during the first few months of its existence. This document was prefaced by the following extract from his report on Drainage made while Sanitary Superintendent of the city of Chicago in 1869:

"From the results of drainage and other sanitary measures carried on in this city, it may be inferred that the judicious

expenditure of money for sanitary purposes is a sound maxim of municipal economy, and from past experience I am satisfied that the mean annual death-rate can be reduced to 17 per 1,000 by continuing in force the present sanitary and drainage regulations, thereby making Chicago one of the healthiest cities in the world."

This was written at a time when the average annual death rate of Chicago was over 24 per thousand. Within the subsequent decade the average annual death-rate had been reduced to 18.48 per thousand, and in 1878 it had fallen to 16.5, or less than the predicted 17 per thousand. Since that period the death-rate has fluctuated with a general upward tendency, so that the average annual mortality for the last ten years is over 20 per thousand. To what extent this is due to increasing density of population and other causes, it is not now proposed to inquire; the fact itself lends significance and importance to the work of the State Board at present in hand, and points to conditions which affect the welfare of the State at large and of every city, town and village within its borders.

The first report of the Secretary embraced the general results of over twelve years of previous study, and specifically of investigations begun under the auspices of the Board in October, 1877,* covering the amount and sources of the Chicago sewage, its flow through the canal and extent of dilution, effects of varying lake levels, force and direction of wind movement, temperature, precipitation and other meterological factors, and chemical investigations of waters collected at various points between Lake Michigan and Peoria. The following prefatory paragraphs are given in full as show ing the comprehension of the importance and magnitude of the undertaking at that time. The report was addressed to the Illinois State Board of Health:

GENTLEMEN:—In pursuance of your instructions, and in the sanitary interests of the State, I have devoted all the spare time that I could to the consideration of the pollution of streams, and especially to the effect of the Chicago sewage on the Illinois river.

The following report, which is sbmitted at this time because immediate action is necessarv, contains the substance of my investigations and the conclusions arrived at thus far; but it is only preliminary to a more comprehensive one which I design to submit to you at a future time.

The factors connected with the drainage of Chicago, through the Illinois and Michigan canal, are many and of a diversified character. To accurately determine the relative effect of each, as meteorlogical changes occur during the year, requires the closest study and involves much labor. The importance of the subject cannot be overestimated, for it involves the sanitary well-being and comfort of at least one-third of the population of the State. I have also conducted similar investigations with regard to the pollution of the Sangamon river, from which the water supply of the city of Springfield is obtained, and of the Cahokia creek, at East St. Louis.

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*The State Board of Health was organized July 12, 1877, and in addition to its functions with reference to sanitary matters, it was also charged with the enforcement of the Medical Practice Act, which took effect simultaneously with the act creating the Board.

## V

### A Sketch of Efforts made to Cleanse the Chicago River.

From the earliest days in the history of Chicago, the Chicago river has attracted anxious observation from a sanitary standpoint, and the anxiety has increased with the increased population of the city and the suburbs, especially since the river has been the receptacle of a large part of the sewage. When a more perfect system of sewerage became imperatively necessary for the health of the city, the widening and deepening of the Illinois and Michigan canal to the capacity of a ship canal was suggested as a means of at once facilitating the commerce of the city and lakes and purifying the river. The one was urged as a proper national enterprise, and the other as a vital necessity for the increasing population of the locality. In July, 1860, the Sewerage Commissioners of Chicago recommended that the canal be enlarged and deepened so as to create a constant current from Lake Michigan into the Illinois river, but their suggestion was not deemed necessary at that time. The pollution of the river increased, however, beyond all expectation, not only by reason of the increase of population, but from other causes. Among the latter was the increase in the slaughtering of hogs and cattle and the packing of meats. In the year 1860, 306,428 head of cattle and hogs were killed and packed, and all of the offal was passed into the sluggish river. In 1863 this business had increased enormously. In that year the number of cattle and hogs slaughtered increased to 1,029,948, and the offal was still swept into the river. There has been a vast increase, year by year, in this business ever since, keeping pace with, or even exceeding, the increasing volume of sewage produced by the rapidly growing population. This accumulation of sewage was partially relieved by pumping-works at the head of the canal; but the relief so afforded could not keep pace with the increase of sewage and offal, and in 1863 a remarkable epidemic of erysipelas occurred, which prevailed exclusively in close proximity to the South branch and to the main river. The great amount of animal refuse thrown into the South branch was supposed to have been the cause of this epidemic. The pollution of the river from these causes increased daily, in 1863 and 1864, and on January 9, 1865, a commission of engineers was appointed "to devise the best plan to cleanse the Chicago river."

This commission presented their report on March 6 of that year, and, after discussing several projects, recommended that, "in view of the facts in the case, the best plan to cleanse Chicago river that we can devise is to cut down the summit of the canal, so as to draw a sufficient quantity of water through it from the lake to create the necessary current in said river." It was urged, as an argument in favor of the proposition, "that the money expended in cutting down the summit of the canal will constitute a part of the expense of enlarging the present canal so as to admit the passage of steamboats of the largest class, an improvement that must soon be made." This plan was adopted, and, in the fall of 1865, the work of deepening the canal was commenced. It was completed in 1871, and, in July of that year, water was admitted at the deep cut from the river. The cut so made at the head of the canal was six feet, and it was computed that at an ordinary stage of water twenty-four thousand cubic feet per minute would flow from the river into the canal.

### Effects Of Pumping The River Into The Canal.

From the year 1860 to 1865 the pumps at Bridgeport were only used to supply to the canal such water as was needed for navigation, and their action in purifying the river, though marked and valuable, was only incidental. But in the latter year the Board of Public Works made an arrangement with the Canal Commissioners to utilize the pumping works as much as possible for the cleansing of the river. It happened, however, in that year, that unusual rains kept the river in fairly good condition without this extra use of the pumps. But the arrangement was maintained, and in 1866 the pumping works were in operation for sixty-two days; in 1867 they operated one hundred and fifty days; in 1868, seventy-three days; and in 1869, one hundred days. The amount of water raised eight feet by them in 1869 is estimated at ten thousand cubic feet per minute. The effect of their operation was marked and favorable, but the result was affected by the operation of other causes, which at times aided and at others hindered the purification of the river. These causes were the variation in the lake level, the local rains, and especially the

constant increase of sewage and offal, resuling from the increasing population, and th staughtering, and other business interests. * These influences were constantly operating and it was found necessary to increase the use of the pumps each year, as is shown i the figures stated above, whenever possible, owing to the limited capacity of the canal which also depended upon the rainfall. As the population increased, and. necessarily the amount of sewage also, the effect of the pumps in cleaning the river was less marke

After the water was let into the "deep cut," in 1871, it purified the South branch an the main river, but it was soon discovered that it effected no marked change in th water of the North branch. The latter continued to be so foul that in 1873 the Fullerto avenue conduit was begun, with a view to its purification. About the time the deepenin of the canal was completed, the slaughtering business was transferred to the stock yard whence the drainage is into the south fork of the South branch, and it was soon appare that the drainage afforded by the "deep cut" and the canal had but little influence i carrying off the drainage of these establishments, though, owing to local and transitor causes, the water in the south fork was occasionally cleansed.

The discussion, which follows in the printed report, of th causes which affect the flow of water from the lake into th canal, the varying lake level, rain-fall, barometrical pressure an consequent wind movement, etc., will be referred to in anothe connection. But the concluding passages of the report, havin reference to a recommendation to the city of Chicago urgin the establishment of the pumping works at Bridgeport, ma properly be cited at this point. The report concludes as fo lows:

This will be the first time that the Board has made a recommendation to the city Chicago in relation to its sanitary affairs. There is another view of the case to whi the attention of the municipal authorities of Chicago shoul be called, which is, that th city has no right to unnecessarily injure the material and sanitary interests of a other part of the State. The community of interests wh ch exists between the citize of Chicago and the inhabitants of the country lying along the canal and river, forbi the injury of either by the other.

It is but just to state that the plans heretofore adopted for the sewerage and drai age of the city of Chicago have been made with a view to such change as the futu might require. The deepening of the canal, which was begun in 1865, was not co pleted until 1871, so that the relief afforded by that measure was delayed six years fro the time when its necessity was recognized. The pumping works can be rebuilt ninety days. My reasons for recommending this course are that the works will furni almost immediate relief without great expense, and without interfering with the proje of a ship canal, or with any more permanent plan which may become necessary for di position of the Chicago sewage.

That the oxidation of organic matter is promoted by the process of pumping will be se by comparing the analysis of specimens Nos. 16 and 17. No. 16 was taken from the mou of tne inlet pipe at the Peoria water works, and contained 83 parts of organic matter a million parts of water, while No. 17, which was taken on the same day, several hou later, after the water had passed through the works, contained only 54 parts. Specim No. 19, taken from the Sangamon river, below the paper mill and distillery, and seve miles above the Springfie d water works, contained 126 parts; while specimen No. taken from the office of the Board at the State House, contained but 73 parts. Specim No. 28, taken from the inlet pipe of the Springfield water works, on December 1 (187 coatained 86 parts, while No. 29, taken from the office of the Board, coniained but parts.

* It is gratifying to be able to here note, that, notwithstanding the enormous increa of the slaughtering business in Chicago within the past few years, the nuisances incide to rendering and utilization of offal have been diminished.

The agency of the pumps in promoting oxidation will be more needed in winter than in summer, because, among other things, in summer the stirring of the water in the canal by the passage of boats promotes oxidation, in some degree at least, but, more importantly, because low temperatures retard oxidation. I remark that any other plan that will afford relief will involve a much larger expense than this will. and much longer time to effect the result. The cost of the pumping works, which were erected by the State in 1859 and 1860, to supply the canal with water for the purposes ot navigation, was $42,158.24. From the statement of their operation, contained in the reports of the Canal Commissioners, I have computed that they raised about ten thousand cubic feet of water per minute eight feet high. The building yet remains, though it is leased to private parties for a short time. I have no doubt that an arrangement could be made with the Canal Commissioners for its use without any expense to the city of Chicago. I am informed that the old lock can be restored at a cost of not more than $10,000. If the whole expense of re-erecting the works should be $60,000 or $70,000, and the expense of operating them should amount to $100 per day, it would be trifling compared to the benefits which would result. I am satisfied that an equitable arrangement can be made with the Canal Commissioners for maintaining the works. The fall from the head of the canal to Lockport, a distance ot twenty-nine milos, is three feet, and the current between those points has a velocity of half a mile per hour at this time. The velocity will increase in proportion as the water at the head of the canal is raised, and the increase will promote the oxidation ot sewage. After a careful investigation, I am satisfied that, with fifty thousand cubic feet of water passing into the head of the canal per minute, the main river and the South branch will be purified; that no nuisance will result from sewage at Joliet and below, and that the potability of the water in the Illinois river at Peoria will not be in the least affected from that source. An increase of water to sixty thousand cubic feet per minute would, in my opinion, take in addition the sewage of the Norlh branch after it has once been cleaned out. and would diminish the nuisance in the South fork of the south branch at least three-fourths.

I am informed by practical men that the increase of current in the canal, which would result from this increase of water, would not materially interfere with navigation, because of its increased depth. The lake level is lower now than it has been for a number of years, but, judging by the experience of the past, it will begin to rise within a year, and will continue to rise during a number of years. But no improvement in the condition of the water in the canal and river can be expected from this cause, for the increased flow into the canal which the higher lake level will produce, will not keep pace witb the increased sewage.

The Fullerton avenue conduit is now completed, and an experimental test will soon be made. I do not share in the great apprehension that exists in the minds of many with regard to the effect upon the pollution of the water supply of the city of Chicago, if the water is pumped from the North branch into the lake, at present; but I think it probable that, under certain conditions, it may pollute it.* Pumping water from the North branch into this conduit will necessarily cause a flow of water from the main river into the North branch. How far this will affect the flow of water into the South branch from the main river under existing circumstances, I am not prepared to say; but I do not hesitate to say that when the current is toward the lake, it will be almost impossible to purify the North branch in this way, for the sewage of both the main river and the South branch will then flow into it. The water in the North branch, north of the conduit, is much less foul than that further south, and it is with special reference to the purification of the latter that the conduit was constructed. But under certain conditions it will happen that the effect of pumping will be to draw off the comparatively clean water at the north end of the branch without materially affecting the fouler water below, as when there is a considerable supply of water by rainfall draining into the branch, which does not amount to a freshet, and changes in the lake level from any

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*While the Fullerton avenue conduit pumped from the North branch into Lake Michigan, complaint was several times made that the water supply of Lake View was polluted by it.

cause may also produce this effect. Of course, when there is a freshet out of the North branch the operation of the pumps is not needed for its purification. At times when the water is pumped from the lake into the North branch its effect will be to create a current into the main river and thence through the South branch into the canal, diminishing or at times cutting off the supply of water which otherwise flows from the lake into these channels. This will add the sewage of the North branch to that of the South branch.

I have already shown that the current into the head of the canal, under the most favorable circumstances, barely keeps the main river and the South branch in a tolerable condition. The addition of the sewage of the North branch to the South branch would render the lower portions of the latter nearly as .oul as the North branch now is. In other words, it would only amount to a transfer of the nuisance and an increase of the nuisance at Joliet and the pollution of the Illinois river. At other times, the effect of pumpi g water from the lake into the North branch, will be to carry the sewage from the latter into the lake through the main river, and when the current is sluggish to cause the latter and, to some extent, the South branch, to become foul and offensive. Either way, the sewage will at times find its way o the lake. If it is desirable or necessary to prevent this, it can be done by increasing its flow of water from the lake into the canal, and it can be done in no other way.

It is better for the city of Chicago that all the sewage should pass into the canal, but it should be so diluted as to prevent injury to the sanitary condition of the country below. If 60,000 cubic feet of water per minute at the head of the canal will not create the necessary current to effect this purpose, I have only to remark that the amount may be increased up to 100,000 cubic feet, which, acco ding to Mr. Thomas, is the present capacity of the canal. Ever since 1872, the south fork of the South branch has been a standing mena e to the health of the city of Chicago. Frequently, when foul odors are blown across the city, characterizeu by a peculiar sickening, deadening stench, and attributed to the slaughtering, rendering, and fertilizing establishments, it really comes from this source. For the purification of this, which is one of the foulest bodies of water within my knowledge, various plans have been proposed; among others, the construction of a large sewer and pumping works, for conveying the water either into the lake or the canal. The condition of this water will be appreciated better than any words can possibly describe it by reference to the analyses of specimen No. 1, from the head of the south fork, which contained 539 parts of organic mattor in a million, and specimen No. 2, from near the mouths of two sewers, which contained 1,233 parts, while specimen No. 4, from the South branch, before its junction with the West branch and South fork, contained only 74 parts per million. From the location of the old pumping works, on the same side and near the mouth of the South fork, I am satisfied that the pumping works will, to a great degree, purify this water. Specimen No. 3 was taken from this fork at the Archer avenue bridge, some distance from its mouth, and contained only 125 parts, showing the purifying effect of the lake water passing through the South branch to the canal.

All of which is respectfully submitted.

JOHN H. RAUCH, M. D.

## To the copy of this communication, as printed in the Second Annual Report of the State Board of Health, is appended the following note by the Secretary:

NOTE.—By direction of the Board a copy of the above report was submitted to the Mayor and Common Council of the city of Chicago, on January 12, 1880, and in order to carry out the recommendations therein contained, an appropriation of $100,000 was made by the Common Council for the purpose of constructing pumping works at the head of the canal. While the matter was pending before the Council, the subject was widely discussed by the press, the Chicago Citizens' Association and the Engineers' Club; conferences were held between the State and city authorities, and an important convention was held at Ottawa looking to pushing the construction of the ship canal from Lake Michigan to the Illinois river. While this last would undoubtedly afford an adequate

and permanent method of disposing of the sewage of Chicago, (provided, that such canal be made wide and deep enough to properly dilute the sewage,) and while possibly some of the numerous other plans which have been since suggested would achieve the result sought for, I see no reason for modifying my conclusion above given, namely, that this resort to pumping is the only plan which can be adopted with sufficient promptitude to accomplish the desired end at an early day." It is immaterial whether this pumping be done from the south fork through a canal connection via the stock yards, or by works located at the Ogden ditch and emptying into the Des Plaines river; or, as is specifically suggested, by re-establishing the pumps at Bridgeport. If this last be done so as to secure a capacity of 60,000 cubic feet per minute when desired, the facts and figures cited in the report demonstrate that substantial relief will be secured for some time to come. With the growth of the city and consequent increased production of domestic and manufacturing wastes and refuse, the time will arrive when 60,000 cubic feet per minute will not dilute the sewage to the point of inoffensiveness, but when that time arrives additional works may be constructed at Ogden ditch with a capacity of say 150,000 cubic feet, and with these two systems the sewage of a population of a million and a half may be satisfactorily disposed of. The vital point now is speedy relief from a grave sanitary danger; one which not only affects Chicago, but which either threatens to, or actually does, pollute the water supply of neighboring communities; which seriously menaces the health of the river towns, and poisons the atmosphere many miles south of the source of the evil. Does not Chicago owe it to herself and to her neighbors to act promptly and efficiently in the matter? Can she afford to invite not only epidemic diseases but an increased death rate? Can she afford to still further incur the risk of pollution of her own water supply, and that of her neighbors on the lake? From the data presented in the foregoing pages it seems obvious that only one available remedy exists for these imminent evils, namely, the removal of her sewage, properly diluted, by the water-courses flowing towards the Mississippi river.—J. H. R.

The work thus begun in 1877 was continued individually by the Secretary long after that date; but owing to want of means the services of professional analysts, observers, and other indispensable assistants could not be commanded until the imminence of an invasion of Asiatic cholera led to the appropriation of a contingent fund by the XXXIVth General Assembly*—subsequently reappropriated by the XXXVth—"to be used only with the consent and concurrence of the Governor, upon the recommendation of the Board, in case of the outbreak or the threatened outbreak of any epidemic or malignant disease * * * and in suppressing outbreaks which may occur and in investigating their causes and methods of prevention; also in special investigations when required by the sanitary necessities of the State."

With the approval of the Governor, the expense of the recent chemical analyses, the collection of samples of water, and the study of the hydrography of the river basins of the State, has been defrayed from this fund, and the results of the work thus

*Owing to the continuance of Asiatic cholera in portions of Europe and in South America having direct commercial relations with the United States, and the consequent danger of its introduction and epidemic spread in this country—a danger which culminated in the arrival of cholera-infected vessels in New York harbor in the fall of 1887—the Board did not feel warranted in recommending the use of any portion of this fund for these investigations. It was deemed prudent to hold the entire amount of the appropriation ready for instant use in protecting the State from an invasion of the disease should it gain a foothold upon our shores. Fortunately this calamity was averted, and meantime the original appropriation lapsed and was covered back intact into the State treasury, whence it was reappropriated by the XXXNth General Assembly as already stated.

accomplished, year by year, have been published in the annual reports of the Board, and in the records of the proceedings of various meetings. The most important of these, prior to this preliminary report on the work of the past twelve months, are to be found in the Ninth Annual Report (for 1886), pages xiii, xiv, xxix, xxx, xxxix—lix, lxiv—lxvi; and in the proceedings of the meetings, January 13-14, and April 21-22, 1887. At the January, 1888, meeting, the quarterly report of the Secretary—after recounting his action in connection with the cholera importations by the steamers Alesia and Britannia, and discussing the question of immigration as affecting the public health—continues as follows:

Turning from this consideration of the subject to our own duty as a State Board of Health, the occurrences above dwelt upon fully justify all the efforts made during the past four years to perfect the sanitary condition of the State, and emphasize the necessity for their further continuance. The results of the unparalleled drought of the past year demonstrate the importance of a vigorous prosecution of the investigation into the sources of and remedy for the pollution of streams and the character of the water supply, not only of cities, towns and villages, but of the country generally throughout the State. Coupled with the chemical and biological examination of water supplies, it is designed to utilize the data obtainable by collecting the various borings made in many parts of the State for coal, artesian wells, gas, &c. These should indicate the character, extent and availability of our sub-surface water supply, and the results of this study and research, while being directly in the line of sanitary interests, will be profitable from an economic standpoint. Only less important than the prevention of disease and premature death thereby, would be the knowledge which should enable the farmers, stock-raisers and others to remedy, as far possible, the results of prolonged dry weather, and to supplement the ordinary sources of supply from the underground reservoirs.

Illinois, though suffering, has, fortunately, been spared the widespread disasters which have been caused by drought during the past year in neighboring States, but the mode of cholera propagation and the extent and severity of a cholera epidemic depending so largely upon the character of the water supply, we cannot rest satified until every community in the State is assured of the best attainable condition of this great sanitary necessity. Wherever typhoid fever spreads beyond sporadic cases, and wherever diarrhea and dysentery are unusually prevalent, it is safe to assume that Asiatic cholera may become epidemic if the specific contagion be introduced, and it will be wise to remedy the conditions which cause such spread and prevalence before the graver disease shall get a foothold.

Touching this portion of the Secretary's report, the following resolution was adopted by the Board at this meeting, to-wit:

*Resolved*, That the necessary preparations be made to carry out the recommendations of the Secretary in his Quarterly Report in regard to the investigation of water supplies and the pollution of streams, and also with reference to the sanitary surveys with a view to placing the State in the best possible sanitary condition during the coming summer.

At the April, 1888, meeting the Secretary reported that—

Work on the investigation of the water supplies of the State has been impeded to some extent by the high stage of water in many of the streams, and lately by the excessive rainfall over large areas. Considerable progress, however, has been made. Time tables for the collection of water supplies at various points—23 in number—between Chicago and Alton have been constructed, so as to make it practicable to follow the

anges, by pollution and purification, in a given body of water from the time it leaves ке Michigan until it flows past the city of Alton. Reports of the chemical and biolo-al examinations are re ·eived in the Secretary's office.

Except with the interruptions noted, samples of water are now collected and exam-ed once a week at Chicago (lake water), Bridgeport, Lockport, Joliet (above and below y), Morris, La Salle, Henry, Peoria, Pekin, Copperas Creek Dam, Havana, Beardstown, arl and Grafton, on the main stream; and from the Kankakee, DuPage, Fox, Big rmilion and Little Vermilion, Sangamon and Spoon tributaries. Samples will also taken from Alton and East St. Louis (Mississippi river water), and from other points found necessary in the course of the work, which will continue six months or more.

In each sample the following de:erminations are made: Total solids, suspended atter, nitrates and nitrites, chlorine, hardness, free ammonia, albuminoid ammonia, ygen consumption and color and odor. By continuing the work through so long a riod, and by making the analyses as fully as outlined, it is hoped that the effect of cidental variations will be practically eliminated. The amount of flow from some of e tributaries is pretty well known, and before the end of the summer it will be known r all, so that we will then be in possession of data complete enough to enable us to ve a fair answer to the question. What is the rate of oxidation in the Illinois river in flow of ‹00 miles, with sources and amount of contamination, and amount of dilution om tributaries, practically known?

The results obtained thus far in this investigation show the importance of a study f the tributaries. The waters of some of these appear to contain a great deal of decay-ng vegetable matter. The character of these waters will be thoroughly studied, as an nderstanding of them is of the highest importance to the sanitary welfare of the com-nunities supplied from such sources. The public water supplies of some of the cities nd towns are also being investigated.

The investigation of the underground water supplies is making satisfactory progress -records from some 60 different localities, in all parts of the State, having been already ecured.

Reverting to the report of 1879 and its recommendations, it s well known that the pumps at Bridgeport were replaced, ıfter delay from various causes; but the capacity re-ommended as a minimum ten years ago is not secured ven at the present time, and the pollution of the Des-laines and Illinois rivers, and the protection of its own water upply still press upon the attention of Chicago. In 1886, a Drainage and Water-Supply Commission was created, for further study of the subject, and after a year's investigation and the xpenditure of some $70,000 in the collection of data, surveys and examinations, the Commission arrived at substantially the onclusion set forth in the first report to the State Board of Health on the subject, to-wit: "The disposal of the sewage of Chicago, properly diluted, by the water-courses flowing towards the Mississippi river."

In their preliminary report (January, 1887,), the Commission-ers outline the main features of the only three feasible methods of disposing of the metropolitan sewage, and give the results of the investigation to date, together with a general conclusion as to the preferable method and an approximate estimate of cost. But they add that they "are not able as yet to give either conclusions or detailed statements of the probable expense regarding all parts of the proposed work, and must defer them until the final report."

This preliminary report was published more than two yea ago, and since that time no effort has been made toward t further utilization of the data accumulated, nor has any ad tional work been done, except that indicated in the followi remarks of the Commission—that is to say, the work now bei prosecuted by the State Board of Health:

"The proper degree of sewage dilution in the new channel d manded a careful investigation. When sewage is mingled wi a sufficiently large quantity of water it not only becomes in fensive, but readily finds the oxygen, which gradually puri it. When the surface is covered with ice a greater dilution necessary for this purpose than at other times when there is constant replenishment of oxygen from the air. The propos waterway should, of course, provide immunity from offense all times.

"The information upon which definitely to decide this qu tion will be given in the final report, as the data have not y been all collected, owing to the necessity of making actual te of the oxidization of the canal water under the ice, which is b ing done for the use of the Commission by Dr. J. H. Rau Secretary of the State Board of Health. The summer conditio are presented in his late report on the Water-Supply and Se age Disposal of Chicago. The result of these analyses will compared with those of other streams that are also pollut with sewage, in order to show the rate of oxidization with va ing degrees of dilution and aeration."

The connection of the State Board of Health with an inves gation which, at first sight, might seem to be purely local w be apparent when it is considered that the sanitary questio involved affect not only the metropolitan area of Chicago b the entire basin of the Illinois-river valley, embracing abo one-half of the entire State and nearly two-thirds the total po ulation. But the work of the Board in this direction is by means confined to the valley of the Illinois; it already cov over 3,500 miles of water-courses—in fact, all the streams Illinois except the Rock river in the northern and the tributar of the Wabash and Ohio of the Mississippi below E. St. Louis a as well as the water supplies of all the State institutions and of t majority of the important cities and towns. An enormous ma of data has been secured, embracing over 1000 chemi analyses of various waters under different conditions—showi the total solids, suspended matter, nitrogen in nitrates, chl ine, hardness, free and albuminoid ammonias, and oxygen-co sumed determinations; the meteorological conditions for series of years as to temperature, precipitation, etc.; the phy cal conditions as relating to questions of sanitary engineerin geological formations, areas of watersheds, inhabitation a other sources of pollution, manufacturing, industrial, etc.; a other factors of the exceedingly complicated problem.

With the working force at the command of the Board it w be the labor of many months to sift, digest and put in ava

able shape for use this mass of material. It is not known that any work of such magnitude has ever before been undertaken in any country. There has been an immense amount of labor expended in investigating the questions of sewage disposal, water supplies and rivers pollution in England, and royal and metropolitan commissions have been formed for this purpose, with large grants of money and the services of experts in all branches. Similar undertakings have done mnch on the Continent and especially with reference to these questions as affecting Paris, Berlin, Vienna and other large centres. The results arrived at in the old world have been carefully studied, as well as the experience and investigations in this country; and in this way, by the process of exclusion, the work has been carried on upon the most promising lines, avoiding labor and effort in directions which have been demonstrated to be unprofitable.

Without dogmatizing upon the results which are believed to be settled by the work thus far accomplished, or venturing opinions on all matters of detail—many of which are still *sub judice*—this preliminary report is confined to an outline of the field attempted to be covered and the general principles guiding the investigation. These latter are fairly well set forth in the succeeding discussion of tho nature and properties of sewage, its relations to health and disease, and the methods of sewage disposal, based upon the physical conditions of the area under consideration. These conditions are embraced under the general head of hydrographical investigations, which lie at the foundation of all discussion pertaining to the rivers and streams and the water supplies of the interior of the State.

The data for a discussion which shall be sufficient to reach the essential truths in hydrography can be had, but their collation and digestion are very laborious and require considerable time and some expenditure.

Mr. Cooley has undertaken this work for the Board so far as it pertains to the basin of the Illinois river and to that of Lake Michigan—an area of about half the State and that of most immediate importance. It is the intention to complete a report from the material now most accessible, which will clear the ground and define more fully the direction which must be taken in order to colleet and utilize all the information which may be had. When this work is completed it will be of more sanitary and economic value and importance than any other physical investigation which can now be undertaken.

The material for a preliminary report has been largely worked over, but at this time, the following matter only has been prepared:

A discussion of the general physical characteristics of the Illinois and Lake Michigan basins with the general effect of inhabitation;

A more detailed discussion of a part of the principal tributary basins;

And a partial report of the distribution and changes in population upon the two basins.

It is intended, as soon as practicable, to complete the discussion of the several tributaries, to complete the population discussion, and to add a discussion of the Illinois Valley proper and also of the physical effects which may be produced by a large and uniform supply of water from Lake Michigan.

It was the intention, and every effort has been put forth, to have this matter in readiness at this time; but the exceeding importance of the conclusions to be reached and the great care and labor, as well as time required to digest the material have made this impracticable. Still, sufficient progress has been made to indicate clearly the general result.

The upper Illinois watershed is underlaid largely by impermeable, non-waterbearing rocks which furnish a scant supply of water to maintain the minimum flow of the streams. The rock is covered largely by unmodified drift deposits, which are impermeable. The consequence is that the streams are fed almost wholly by surface drainage; thus the flow in them is profoundly dependent upon immediate meteorological conditions in regard to rainfall and evaporation. There existed, however, in nature on a large proportion of the area lakes, marshes, bogs, and wet prairies, while timber covered the ridges and higher knobs; and the banks of streams, or those portions of the watershed which were dryest, naturally drained on account of the more permeable surface. All this exercised a reservoir action upon the waters and distributed them more equably to the streams.

Upon watersheds in which the deposits overlying the rock are permeable, and the rock permeable itself, inhabitation produces no material change. Such characteristics do not obtain in the upper Illinois basin except to the most limited extent.

The surface drainage continually going on in the general tiling of the heavier soils, the ditching-out of the sloughs, bogs and prairies and the wholesale reclamation of the great marsh areas by drainage districts, destroy all the natural reservoirs for the equalization of flow to the streams, except those formed by the lakes especially developed upon the watershed of the Fox. In lieu of such reservoirs the surface is generally left more permeable, and to this extent is regulative; but after periods of drought, or even the long dry weather of the later summer so characteristic in this region, this effect is lost, as compared to natural conditions, upon all areas not continuously saturated with water. Upon such areas the effect is radical so far as the impounding of floodwaters and the maintenance of the minimum flow are concerned.

It is current opinion among those living adjacent to the watercourses, that perceptible effects have already occurred. A detailed consideration of all the changes that may be affected by inhabitation within the next fifty years, shows clearly that the

most radical alteration in the flow of the streams will result, and it seems possible to predict clearly what the nature and extent of these changes will be.

From the data set forth in the appendix,* it is concluded that the flood contributions from the Desplaines will not be largely increased, while the dry-weather flow may be reduced one-half to two-thirds its present amount, and that with certain changes which may be effected in the regimen of the river near Summit, and which do not involve the drainage of Chicago, the maximum may be increased over 70 per cent.

The drainage of the great marsh areas in the Kankakee basin will, however, produce the most profound effects. It is expected that the flood volume will be increased over four times at Momence, and the low-water volume reduced to less than one-eighth its present amount. At the mouth of the river the flood volume will be about doubled, and the low-water volume reduced to about one-sixth. In addition to this, as the immediate underlying deposits of these marshes are almost wholly sand and gravel and the grades steep, it is anticipated that until these drainage ditches have enlarged and reached a condition of stability in more resisting deposits, great quanties of detritus will be carried to the Illinois.

The effect of inhabitation upon the Fox will be less pronounced than on any other tributary. Still the floods will be sensibly increased and the minimum flow diminished. Mazon river and Bureau creek now run practically dry in some seasons. This period will be simply prolonged and floods increased. The two Vermilions have not yet been considered, but springs from the rock give them some low-water flow which is permanent.

The general effect upon the Illinois will be to increase the floods by 30 to 40 per cent. down as far as the Sangamon, and perhaps to a lesser degree below. The low-water volume will be reduced to say one-fourth or one-fifth its present amount above the Fox; to less than one-half below the Fox; to about one-half between Peru and the lower tributaries; and, perhaps, by a lesser amount in the lower third of the river.

A considerable proportion of these effects will occur within a few years as a result of wholesale reclamation projects. They will be accompanied by an enormous increase in the supply of detritus. This supply will not keep up indefinitely in the future, but at all times it will be multiplied over past conditions, owing to the increase in tillage and the more complete ditching of the lands.

The effect upon the upper Illinois above Utica will be to increase the height, range and frequency of overflow, and perhaps to cover the lands with infertile deposits of sand. This portion of the river has, however, ample declivity and the bed will not be materially choked by such deposits. The effect upon

* The Illinois River Basin in Its Relations to Sanitary Engineering. By L. E. Cooley, C. E.

the alluvial section of the Illinois from Utica to Grafton, 2 miles, will be most profound.

The grade of the river in low water does not exceed 26 fe or is only about 1⅛ inches per mile. When the Illinois is hi and the Mississippi low it has been as great as 35 feet, and the contrary with a low Illinois and high Mississippi backwa sometimes extends to Peoria. In fact, there have been hi waters in the Mississippi which would give five feet at Peru no water went down the Illinois.

The area of the bottoms is about 600 square miles, entir overflowed in high water to the second bottoms or terrac In fact, the banks are only about 12 to 14 feet high down Henry, and from 8 to 12 feet thence to the mouth, while flo heights are double these amounts. Only a small proporti of the entire bottom area is cultivable, a large proporti being in lake, bayou, slough and marsh, and still another p tion so low as to be only available for grazing. That th conditions are generally unhealthful it is unnecessary to say

The natural river has never been able to maintain an effect channel against the washings brought in by the tributar even when the watershed was unbroken by tillage. The obstr tion of the stream by dams has increased the tendency deterioration which in any event would accompany the inha tation of the watersheds. The evidence is undoubted th deterioration of the main channel and choking of the beds streams across the bottoms with local overflows are going at a rate which is directly noticeable.

All streams of an alluvial character that are adjusted to th work of carrying the detrital supply and of similar volume the Illinois, have grades several times as great, with th banks built up usually to extreme high water limits, and t velocity required to clear and maintain the channel free fr deposits is upward of two miles an hour. None of these con tions here obtain, the Illinois having a grade only compara to the Mississippi at New Orleans or to the outlets of the gr lakes, running deep and with enormously greater volumes so to give a channel-maintaining velocity.

The ultimate natural effect of the changed conditions in t lower valley of the Illinois, will be to convert it into a cont uous marsh, without well defined drainage lines other than chain of sloughs, except, perhaps, at the lower end, gradua filling up its bottoms until in ages of time it may probal become adjusted to its new labors. It is doubtful if man c counteract these tendencies or more than postpone their co summation without a radical change in conditions.

It is evident that the only stream which will be in harmo with all the requirements is one of such large and constant v ume and great depth as will give sufficient velocity to mainta a channel upon the present grade. If we could suppose su large and constant volume to be permanently drawn from La Michigan, its results would be wholly beneficial after the imn

diate temporary effects accompanying its introduction are over. The quicker this is done the sooner will the present deterioration be arrested and the stream prepared for its growing duties as a drain to its watershed.

The first effect in raising the water surface, except immediately at Peru, will be less than that now occasioned by the existing dams and those in process of construction. If the dams are taken out and such improvements made in the bed of the stream, in conjuction with the introduction of a comparatively small volume of water, as will make it useful for navigation, the present conditions will not be reached at any point, and through natural and artificial forces the gradual improvement of the channel will go on, with a certain improvement in flood height and in the condition of the bottom lands. In fnct, only by such a plan is there any hope for a permanent reclamation of the lower Illinois valley, or relief from the changed conditions wrought by inhabitation.

Except as to a limited extent of the bottom lands, it is possible to make such alterations in the bed of the river above Utica, as will largely avoid any ill effects from the introduction of a steady and uniform volume, and no doubt this will be the least expensive and most in harmony with public policy. Should a radical improvement be made for a channel of large depth the conditions will be profoundly and favorably ehanged.

Whether a channel supplying a large and uniform volume of water from Lake Michigan, is now justified or not for the needs of the city of Chicago, it is a serious question whether outside State interests in the near future may not be served thereby as an economic and sanitary provision. There are many large and growing cities situated upon the streams of the Illinois watershed, several of them in the immediate valley. In very few instances are these cities so situated as to make land disposal of their sewage at all practicable and in others only at very large expense. Chemical precipitation thus far has only succeeded in removing about one-half the putrescrible matter, the effluent going to the river. So far as science may now determine, the cities of the Illinois valley must, perforce, use the river for sewage disposal.

In the case of the city of Joliet, the natural flow of the stream is inadequate at times to dilute the sewage of a populaticn of 1,500 people, and of less than 5,000 for several months of each year. At Morris, it will in the future be inadequate at times for 40,000 people, and from Peru to the Sangamon for 125,000 population. In some recent dry-weather years, over half the low-water volume down as far as Peoria has come from Lake Michigan, and with it the sewage of Chicago. While the fish have not been disturbed at such times below the Kankakee, except in winter, yet below Peoria the organic wastes from the distilleries and cattle pens so pollute the water as to kill them. It is a question whether the present sanitary condition of the lower Illinois would be not worse if the flow of water from Lake Michigan were excluded.

In a stream largely of surface drainage like the Illinois, it i apparent that the aggregate organic matters contribut annually from the vegetation which grows luxuriantly over i entire watershed, and which has been contributed for ages, i far greater than that produced by all the inhabitants who ma live upon it or drain into it, and that so far as its effect o health is concerned this may be just as potent in breedi disease. The analyses of the waters in their natural conditi when compared with the total volume throughout the seaso makes this apparent. It is also apparent that they do n afford a commendably potable water for domestic use.

If a channel for supplying a large volume of water from La Michigan is constructed, it is a matter of economy from an e gineering standpoint to give it depth rather than great widt as far as Lockport and perhaps to Lake Joliet. As has al been shown, the physical conditions of the lower river dema that it be deep rather than wide for effective work; such wi be the natural tendency and this may be greatly assisted b relatively slight artificial means. With these two factors fixed it is probable that the intermediate river will be improved o the same scale.

From the important national features of such a channel an the relations that the lakes may bear to the Mississippi it i not likely that the first efforts will be the end—that the volum furnished may not be greatly increased in time. The consumma tion of such works if judiciously developed will be wholly bene ficial.

Further study of the data already accumulated, and very possibly additional data, will be required to determine with accuracy the limit necessary for the effective dilution of sewage but enough is now known to make it safe to say beyond doubt that the limit is within the practical means of accomplishment It is hardly supposable that any body of men responsible fo large expenditures would make a mistake in this particular, sub ject, as they are at all times, to the fundamental law which would render all their expenditure useless in the event of a unsanitary condition resulting. Still it is a matter in which th State Board should be authorized to exercise discretion in th interest of communities whose sanitary welfare may be directl involved.

The distribution of population, to which much study has bee devoted, is most instructive and interesting. As sanitary ma ters relate largely to communities, the increase in town and cit growth is significant of the constant need of fuller sanitary pr visions. It is also noticeable that the urban population of tl city of Chicago is about equal to that of the balance of tl State, double that on the Illinois watershed and many tim that in the Illinois valley. These facts are matters of deepe interest in considering the necessities of the metropolis and wa rant the most liberal spirit consistent with no material impai ment of the rights of the lesser communities. If the solution

the sanitary necessities of one of the most important cities of the country can be made of like benefit to many other communities and of vast importance to the commercial, economic and sanitary interests of a large portion of Illinois, there should be no question as to a wise State policy on the subject. Nor, on the other hand, should there be any risks incurred through action based on imperfect or inaccurate information. The fullest study should be made of all the factors in a problem of such magnitude and complexity.

To what extent this study may be carried can be only faintly outlined in this preliminary report. The nature and properties of sewage, its relations to health and disease and the various methods of disposal all demand careful consideration. Broadly stated, sewage comprises all the wastes of a town which can be carried off by flow in pipe or conduit. What to do with it has always taxed the resources of civilization. To allow it to saturate the underlying soil and the ground water, or to pollute the water supply, is disease breeding. Its unguarded decomposition is neither healthful nor tolerable. The problem has usually been solved in the simplest and cheapest way possible, consistent with the rights of others.

Contrary to popular belief, experience has shown that sewage is not of great value as a fertilizer. Its chief constituents are the animal wastes, in both solid and liquid form, and even the polluting elements of the solids are soon dissolved, leaving comparatively inert matter behind—the ashes, as it were, of the combustion process which we call decomposition. These constituents, the urea principally, undergo easy and rapid decomposition, dissipating the fertilizing elements in the form of ammoniacal gases. By the time sewage can be applied for fertilizing purposes, it has usually lost much of its value. To realize its utility, it should be collected before it becomes diluted with water and then mixed with non-fertilizing elements, and fixed in form to be used at convenience. This has been tried in the pail system for closets, and abandoned—except in small places—for the present system of plumbing in connection with water-carriage and a public water-supply.

For untold ages, since the waters were gathered together, the earth has been clothed with verdure and filled with animal forms—organic life that dies and undergoes dissolution, sending to the air, the soil and the waters the products of decay; how much of life we cannot tell, but the limestone, the marls, the carbonaceous deposits, the residual oils in the rocks and the pent-up gases bear witness to some small fraction. And still the world is habitable.

Sewage, like all other organic matter, undergoes decomposition, and in much the same way. A low-water volume of 90,000 cubic feet per minute in the Ohio river receives the sewage of Pittsburg and Allegheny, and is visibly polluted; after receiving similarly polluting accessions from other towns, the water

is pumped for the public supply of Cincinnati; and when Ci cinnati has contributed its filth the water is pumped for Lou ville. Minneapolis and St. Paul send the sewage of over 400, 000 people into the Mississippi, with a volume of 400,000 fe at low water, and cities and towns below use the water. Ch cago sends its sewage to the Illinois, and ice has been cut fro Peoria lake for local use and export: if it were much pollute the melting and subsequent heating would disclose the effluvi to the senses. Pollution disappears with distance and tim and water, earth and air are thus purified. If the supply water or of earth or of air is sufficient, the results are n greatly different from those obtaining everywhere and constantl dissolution completing the cycle of all of nature's operations i organic life. It is, in a sense, a question of degree: if we co centrate too much, the results are undoubtedly actively prej dicial to health. But there are gross exaggerations in the stat ments on this point, We could not live, if all were true th has been written upon the subject.

Decomposition is largely a vital process, bacteria feeding o organic wastes, digesting or reducing to a lower plane, break ing up the complex substances with the evolution of vario gases—not unlike the higher types of life, and the products ar similarly dangerous if too much concentrated. The gases gene rated in the vital processes of human life are poisonous, as i a crowded room; and we therefore provide ample ventilatio Finally, in all these vital processes, the complex organic sub stance is reduced to its inorganic elements.

These lower types, these micro-organisms, are a world in them selves, of different families, groups and varieties, and their growth and multiplication play an important part in the various pro cesses and varieties of fermentation and decay. Their germs are everywhere present to plant organized matter. Heat kills them, and hence we cook meats, vegetables and fruits, and seal i air-tight cases. The desiccating winds of the "far west" sa their vitality, and there meats dry up in the open air withou decaying. Freezing renders them dormant for a time. Anti septics destroy them. The great triumph of modern surgery i the Listerian method of performing operations in a sterilize atmosphere, and using antiseptic washes and bandages, thu excluding or destroying germs from wounds, and avoiding su puration, painful healings and blood-poisoning.

Butter becomes rancid, meat tainted, milk soured,—these a varieties of the vital changes. We use salt or smoke (pyroli ueous acid), or cook the substance so that it will keep. Hea moisture and the presence of oxygen make all organic matt suspectible to bacterial life. When the food is exhausted, t bacteria become capsuled or encysted, as it were; they are th more difficult of destruction, and drift as seed to renew th vital processes wherever the conditions favor. These operatio are arrested sometimes from very excess of bacterial produ before their food is exhausted. One variety of these changes

hat of alcoholic fermentation. In this sugar is changed to lcohol, and the change is arrested when the alcohol reaches a ertain per cent; but the alcohol itself may be reduced by acetic rmentation, to vinegar, a still lower plane, and again to its nal inorganic elements. Another type of organism would proace a fermentation and product entirely different.

The ordinary bacteria of decomposition are not of themselves sease-breeders; in other words they do not effect a lodgement - multiply in living tissue through germ ladened air that may inhaled, or waters that may be drank, though they will proace blood-poison in wounds and even death in capital cases here the vital forces are low. The exhalations from an area active decomposition are offensive, producing in many perns headache or nausea, lowering the general tone of the sysm, and making it more susecptible or predisposing it to the dgement of specific disease germs. Decomposition less active nd far more offensive and dangerous will go on with an infficient supply of oxygen. The remedy for all this is greater lution, greater dissipation, a freer supply of oxygen. The ases from our chimneys are deadly in concentrated form, and r much the same reason, but they are harmless if sufficiently ffused and diluted.

The modern theory of disease is that specific germs effect a dgment in those organs or tissues that are susceptible from ay cause, and destroy or impair their functions or produce sions, and death ensues from impairment or destruction of gans, or from the poisons generated. If the vital forces be eat the disease may "run its course"—that is, the particular bstance upon which the bacteria feed will be exhausted or e products which are by them generated will arrest the mulplication of the specific bacteria.

Various causes may lower the vitality and impair the function a part or pre-dispose to disease, or such pre-disposition may hereditary, but the disease itself is not hereditary. The point that the particular parts affected are not up to the proper tal standard,—partially vitalized tissue being attacked by pecific bacteria and only devitalized matter by the ordinary acteria of decomposition.

This theory is based on the fact that a disease incubates and rows, while, if the agency was a simple poison, its maximum fect would be produced without any period of incubation and rowth. Several of these specific bacteria—those of typhoid or nteric fever, of consumption, of the malarial fevers, of Asiatic holera, of malignant pustule, of splenic fever, diphtheria, rysipelas, pyæmia, septicæmia, etc.,—have been isolated and heir habits studied; while by analogy the history of others is nferred. Some are indigenous to man; some are shared by the ower animals; some come from vegetable decomposition under pecial conditions; some spread by contagion and some are pecifically infectious; some do not propagate themselves and some roceed from the general infection of the originating cause and

not from the individuals affected. In some cases, the germs have remarkable fecundity under special conditions, but outside their proper or specific environment their vitality is limited.

It may be seen from this summary of the general principles of the present germ theory, that disease may be largely preventable when all these things are fully understood. This is the field of all sanitary work and study at the present time. Consumption is indigenous on heavy soils, with a high groundwater plane; marshes and vegetable decomposition in stagnant water, cause malaria; typhoid or enteric fever is generally communicated through drinking water, as are also the diarrheal and dysenteric disorders; while diphtheria is often due to defective house plumbing; and so, in various ways, are the causes of all zymotics assigned with more or less certainty.

The general theory of disease thus given is by no means fully accepted nor can it be until investigation in a very difficult field has progressed much farther. It is the extreme view, however, so far as disease may be preventable by purely sanitary agencies. For the purposes of this investigation it is not necessary to develop it beyond its application to sewage and sewer gas as media for spreading the germs of specific disease, and to this extent the theory possesses a working value which fully justifies the outline of its salient points presented in this connection.

In the investigation of specific bacteria they are isolated and cultivated in solutions of beef tea or other nutrient, carried in gelatin. Plates are prepared covered with a film of the nutrient, and the fluid containing the specific bacteria is drilled thereon in rows. Their multiplication is shown by the lique faction of the gelatin and can be studied under the microscope. I a single *bacterium termo*—the ordinary agent of decomposition— by accident gets on the plate, the culture is destroyed; it wil multiply so fast and is so hardy that the specific germ stand no show whatever. The plain and very important inference i that the *bacterium termo* is the wolf among these low forms o life and that in his habitat, or in any area of active sewag decomposition, no specific germ can survive, much less propa gate. If this is so, then in any place of actfve decompositio or after decomposition has begun and is partially completed, o after it is entirely completed, there is no danger of speci disease, except so far as has already been alluded to in discus ing decomposition. The history of such places seems to bea out this inference. If it were not so life could not be sustain in their vicinity.

The danger of sewage as an agent of zymosis is comprehend before that point—active decomposition—is reached. The sp cific bacteria may infect the house connections and may rea the sewer, possibly the main; but as soon as an area of acti decomposition is reached they are disarmed and destroyed. I Chicago the sewage undergoes decomposition in the mains, a sewer-gas passing back through the house-connections may car

the specific germs into the dwelling; but ordinarily they probably do not get far in this direction. The danger is in the vicinity of the habitation. In rain or floods, sweeping everything out rapidly, there is danger of their being carried a long distance away and infecting the water supply. The dejecta of one typhoid-fever patient thrown upon the snow of a watershed, when melted in the following spring, has been known to infect the water-supply of a town and produce over 1200 cases. But the researches of Prof. Lester Curtis, M. D., who has made the biological investigations in connection with this work, fail to reveal the presence of any specific disease germs in the waters of the Illinois and Michigan canal or in those of the Desplaines or Illinois rivers and tributaries.

The nuisance occasioned by the pollution of watercourses has in recent years demanded other methods of sewage disposal, as by "broad irrigation" or sewage farms and by chemical treatment. The merits of both these methods have been greatly exaggerated, and they are never applied except under compulsion or when nothing else is available. They have never made any return on the large investments required and have rarely paid operating expenses.

The soil underlying cities becomes polluted; cess-pools saturate the ground in the vicinity; filth accumulates in and upon the soil. Sanitary literature is filled with instances of the pollution of drinking water from such causes, often at considerable distances and in the most unexpected manner. This, in a sense, is crude land disposal and it is always dangerous. It is argued, however, that when it is done systematically on a sewage farm that the method is perfect.

The fact is the soil must be suitable, and be handled in the most judicious manner. Pure sand will not dispose of sewage any more than a brass strainer. It simply clarifies, and the effluent is otherwise unchanged. In time organic matter will accumulate so as to furnish a nidus for bacteria, and when the sand is fully charged—in other words, becomes a soil—it will accomplish its work. Impermeable soils simply accomplish surface decomposition by air exposure, a method which is, certainly, as bad as can be devised. When broad irrigation is used in application to crops as needed, great areas are required and enormous distributing systems, much greater than it is practicable to provide for or to reach from large cities. And this must be supplemented by filtration-beds for use when irrigation is not required.

In the filtration plan the ground must be carefully prepared at large expense, and the amount that can be applied is strictly limited or a nuisance is created, and the land should rest in alternate years to rot out. The crops that can be raised are limited in variety, and much greater than the market demand. In a financial sense, both broad irrigation and intermittent filtration have been disappointing to their promotors, although they may be very useful resources for sewage disposal in needful

cases or under especially favorable conditions such as obtain in Edinburg, where the Craigentinny meadows have been used for broad irrigation in a crude way for over 200 years.* Both in Paris and Berlin attempts are made to dispose of the sewage in this manner—*i. e.*, by broad irrigation and intermittent filtration—but the results are unsatisfactory in the French capital; while, notwithstanding the exceptionally favorable conditions, there are already grave doubts as to the wisdom or expediency of longer relying upon this plan for the disposal of the Berlin sewage. The Royal Commission on Metropolitan Sewage Discharge, in its final report, summed up the question in the following terms as applied to London, and they are substantially applicable to all large cities:

"On the whole, therefore, with regard to broad irrigation, we are of opinion—

"1. That, generally speaking, it offers a satisfactory mode of disposal of sewage, where circumstances admit of its application.

"2. That it offers the most likely means of realizing some portion of the value of the sewage.

"3. That when properly arranged and carefully conducted, the effluent will be effectually purified, but that under careless management the purification may be incomplete.

"4. That it need cause no danger to health.

"5. That with proper care, when applied on a moderate scale, it need cause no serious nu sance to the surrounding neighborhood; but that if improperly managed nuisance may arise, and may become considerable.

"6. That there may be a danger of the pollution of subsoil waters.

"7. That to apply broad irrigation to the metropolitan sewage near the outfalls would be a matter of great difficulty, on

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* As this Edinburg illustration is often cited by the advocates of the land disposal of sewage, it is worth while citing the best authorities on the subject. The English Local Government Board Report of 1876 spoke of the case as follows:

"The Craigentinny meadows afford the strongest example of pecuniary success in the rough and ready use of crude sewage to produce rank crops of grass. The case must, however, be considered with all its surroundings. Thr crude sewage flows down from the older part of Edinburgh without stint or charge towards land having little value in its natural state, as it is for the most part blown sand from the adjoining estuary. The sewage is received at a point sufficiently elevated to allow of its gravitating on to the land to be Irrigated, the effluent escaping down to the boundary line of the sewage farm, which is the sea. The land is of low value as agricultural land, the sewage is abundant, far more than is required for the area irrigated; it costs nothing to the proprietor of the land, and its use, its abuse, or its waste, is under no local control; it is applied in the cheapest way, and the crops are put up to auction in one acre plots every year, the purchaser cutting and removing the grass at his own cost. The mode of irrigation is uncleanly and rude, and there is undoubtedly at times an offensive smell from the carriers, from the rudely trenched irrigated surface, and from the effluent water. During the winter the sewage is allowed to flow direct Into the sea."

Dr. Letheby in his book of 1872, said: "On the Craigentinny meadows at Edinburgh, where large results have been achieved, all sanitary considerations are abandoned, and the sewage is allowed to flow upon the ground in such enormous quantities as to convert the locality into a stinking morass, which is a public nuisance; besides which the effluent water is so foul as not to be admissible into any decent water course, and therefore runs directly into the sea. These meadows have long been notorious as the most filthy and offensive plots of cultivated ground in Great Britain. It is clear, therefore, that the Edinburgh example cannot be considered as any guide for the cases most likely to occur in practice, where the principal object must be to provide a means of getting rid of the pollutions and nuisances caused by sewage, to which the realization of profit must be only subsidiary."

account of the enormous quantity of land required, its great probable cost, and the powerful opposition that would be raised against such a purpose.

"8 That for these reasons we do not recommend any attempt to supply this system as a remedy for the evils of the metropolitan sewage discharge."

For small towns, where suitable land is available in sufficient quantity within a reasonable distance; where the storm-water is excluded from the sewage; where the effluent may be properly disposed of; where there is no danger of contaminating the subsoil waters by percolation nor other water supplies by surface drainage; where scrupulous care may be continuously exercised and an adequate "plant" is provided—under such circumstances this system should give fairly satisfactory results. But even at Pullman, where the most favorable conditions obtain the permanent and unqualified success of the experiment is open to question.

Chemical treatment is also much misunderstood. It accomplishes only partial purification. Various precipitants are used —lime ordinarily—which simply coagulate and throw down the albuminoids along with any suspended matter. The effluent has still from forty to sixty per cent. of putrescible matter and will undergo secondary decomposition. Oxidation *per se* is not yet a commercial process, being applied only in the laboratory in analyses of sewage or on the broad scale of nature's operations.

The sludge precipitated from sewage by chemical treatment has not realized any special value as a fertilizer. By the use of filter process and other treatment it has been endeavored to make it more available, but without material success. It is given away, piled up and gotten rid of in any way possible in foreign cities. If it has no value there it certainly will have none in this country in the immediate future.

Water disposal may become a nuisance the same as land disposal and for very much the same reason—inadequate provision. When the oxygen dissolved in water is in excess so as to accomplish normal decomposition, the gases are resolved into their simplest forms; when the oxygen is deficient—in other words, when the degree of dilution is adequate—offensive and more dangerous gases are generated; it is analogous to imperfect combustion by which smoke is produced. The most powerful agent to disassociate such gases is sunlight, but in heavy weather or in the dark they may continue to offend remotely. The oxygen in the water is removed slowly by contact with the air, but not with sufficient rapidity to supply any original deficiency. The appearance of sewage-polluted water changes radically when the oxygen is exhausted and the margin between a bad condition and one comparatively good appears to be narrow.

The attempt to decompose sewage rapidly by aeration has not been successful. As decomposition is largely a vital process it is apparent that it cannot be stimulated beyond a certain rate.

In other words, time is an essential factor. Were oxidatio the sole agent, then it would undoubtedly be accomplish much more rapidly.

Running water in a river of large proportions rapidly diffus the sewage and brings it in contact with the oxygen and tl supply is more readily maintained by all the water, as it flow coming successively in contact with the air. In lakes the diff sion is much slower, liquids not mixing with that rapidity n in the manner characteristic of gases. It is now becoming settled dictum of sanitarians, that "sewage is decomposed l the influences acting in running water and leaves only its skel ton in the form of the inorganic chlorides."

The writer, whose words are here quoted, has fallen into a error which it seems necessary to correct, mainly because of tl authoritative character of the work in which it appears. In tl article "Water," in the Reference Hand-Book of the Medic Sciences (Vol. VII, page 714,) occurs the following:

Dr. Rauch, of Illinois, (Proceedings State Board of Health, 1886,) makes even a grea claim upon our faith than Professor Leeds. He holds that experiments conducted his laboratory demonstrate that the sewage of Chicago is so nearly destroyed in a ca flow of thirty-three miles to Joliet, that, if the same rate of purification held good bel that point, no trace of the sewage would be found ten or twelve miles farther dov Subsidence, he considers to have had little to do with the purification, as the passage boats necessarily nuliified its influence; and there was no di ution of the contents the canal, as little or no rain fell during the period cove ed by the observations. T quantity of water which carried away and thus effectually disposed of this sewage of city of 500,000 inhabitants, is stated to have been about 45,000 cubic feet per minu "Over one-half the sewage-pollution disappears before reaching Lockport, twenty-ni miles below Bridgeport; and nearly one-third of the remainder is lost in the next fo miles, the increased rate of purification in this distance being due to the mechani agitation of the water by falls, wheels, lockage, etc., and the greater extent of surfa exposed to aeration by the union of the canal and the Des laines river.". These sta ments would be of immense importance were they sustained by collateral evidence; b unfortunately, those analysts who have had much practical experience in following t track of sewage in its passage down stream, wili recognize in these results: 1, T analysis of a fresh and turbid sewage at the starting point, the solid particles of orga matter giving a high rate of impurity; 2, the analysis of a partly sedimented sewage those particles disappear from the water; and, 3, the dilution effected by the Desplain river.

For the benefit of the "analysts who have had much pra tical experience in following the track of sewage in its passag down stream" it should be stated that—1. The analysis itse showing 12.563 parts of free ammonia per million, is that anything but "a fresh and turbid sewage at the starting point on the contrary it is a sewage in an advanced stage of decor position; 2, "sedimentation" in a current with the velocity that in the Illinois and Michigan Canal is a physical imposs bility, and this entirely apoart from the influence of the passag of boats; 3, it is expressly stated in the text quoted that the was "no dilution of the canal," which contents were the sc subject of the various analyses at Bridgeport, Lockport ar Joliet; as a matter of fact the Desplaines river above the poi of junction with the canal had ceased to exist as a watercour

during the period under observation, and the contents of the canal were undiluted from any source after leaving Bridgeport until several miles below Joliet. Since this experiment has been thrice repeated in the recent work—in the winter of 1876-7, in the summer of 1888, and again within the past three months—the original report is here appended for convenience of reference.

### RATE OF PURIFICATION, BRIDGEPORT TO JOLIET—SUMMER OF 1886.*

Advantage was taken of the remarkably dry season to determine the rate of purification of the water in the Illinois and Michigan canal and in the Illinois river during June, July and August. As shown by the preceding table, the rainfall was so light up to the middle of August that the contents of the canal from Bridgeport to Joliet, where it unites with the Desplaines, were practically unaffected by dilution. The conditions were as though the experiment was conducted in a laboratory. Whatever purification occurred between the points mentioned was due to sedimentation and oxidation, and mainly to the latter, since the passage of boats would interfere with the former.†

During a tour of inspection accompanying the Governor, on May 30 and June 1, the attention of the Secretary was attracted by these conditions, and preparations were at once begun for taking advantage of the opportunity presented. Some delay occurred in securing collections of the water at points below Joliet, and it was not until June 26 that the first samples were collected, and then only from Bridgeport, Lockport, Joliet, Ottawa and Peoria.

[A table, embracing details of 62 chemical analyses, which follows in the report, is here omitted as containing much matter not bearing upon the point under discussion.]

The following table gives the averages of the different analyses of samples collected at each place on the same day:

| PLACES. | Free Ammonia. | Alb'm'd Ammonia. | Oxygen used. |
|---|---|---|---|
| | In 1,000,000 parts. | | |
| Bridgeport | 26.563 | 1.633 | 26.20 |
| Lockport, 29 miles below | 12.733 | .753 | 11.01 |
| Joliet, 33 " " | 9.426 | .432 | 9.34 |
| Ottawa, 81 " " | .413 | .243 | 5.30 |
| Peoria, 159 " " | .027 | .194 | 4.81 |

The respective percentages of loss shown in the following may be taken as the measure of the rate of oxidation in the canal during the summer months, unaided by dilution:

| PLACES. | Free Ammonia | Per cent of loss. | Alb'm'oid Ammonia | Per cent of loss. | Oxygen used. | Per cent of loss. |
|---|---|---|---|---|---|---|
| | In 1,000,000 parts. | | | | | |
| Bridgeport | 26.563 | ........... | 1.633 | ........... | 26.20 | ........... |
| Lockport | 12.773 | 52.1 | .753 | 53.9 | 11.01 | 58.0 |
| Joliet | 9.416 | 26.1 | .432 | 42.7 | 7.34 | 33.4 |
| Total per cent of loss between Bridgeport and Joliet | 64.6 | ........... | 70.36 | ........... | 72.0 | ........... |

* Ninth Annual Report, Illinois State Board of Health.

† It should be noted that the current in the canal, nine-tenths of a mile per hour, is of itself sufficient to prevent sedimentation: and numerous dredgings of the bed of the canal show no traces of sewage subsidence.

The different ratios of loss of free ammonia and albuminoid ammonia are accounted for by the partial conversion of the latter into the former. The measure of the purification is indicated by the means of these losses,—that is, about 70 per cent in 33 miles. In other words, over one-half of the sewage pollution disappears before reaching Lockport, 29 miles below Bridgeport, and nearly one-third of the remainder is lost in the next four miles, the increased rate of purification in this distance being due to the mechanical agitation of the water by falls, wheels, lockage, etc., and the greater extent of surface exposed to aeration by the union of the canal and the Desplaines river.

During the period of 42 days covered by the examinations of which these are the means, there were only 3.04 inches of rain, while the average amount for the corresponding period during the preceding 15 years is 5.14 inches, and during the corresponding weeks in 1885 there were 3.15 inches, or more than four times as much. From February 1 to August 15 it was so dry that the light rains during the six weeks under consideration were quickly absorbed by the earth or evaporated before reaching the streams. As before remarked, there was no dilution of the contents of the canal between Bridgeport and Joliet, 33 miles,—and the loss of sewage pollution must be attributed to oxidation.

If the same average rate per mile obtained after leaving Joliet, the pollution of the canal by the sewage of Chicago should disappear within the next 10 or 12 miles, or at about Channahon. An examination made by the Secretary on June 1 corroborates this estimate. There was no evidence of sewage pollution, discernible by the senses, in the canal below the Kankakee feeder, which is three miles below Channahon and 48 miles from Bridgeport. The purification of the Desplaines is even more rapid than this, owing to its shallow, wider and more broken flow insuring more perfect aeration.

It is stated that an average of about 45,000 cubic feet per minute was being pumped from the river into the canal during this beriod. Whatever the quantity it is obvious that if the volume of dilution had been increased by 20 per cent. the contents of the canal would have been entirely inoffensive to the senses on reaching Joliet—not alone through the increased quantity of oxygen this additional 20 per cent. of water would contain, but also because of the improved condition of the river and its branches which would result from the continuous removal of the sewage and foul wastes.

RATE OF PURIFICATION, BRIDGEPORT TO OTTAWA—WINTER OF 1886–87.

During the months of December 1886, and January, 1887, an investigation was made to determine what effect low temperature and the freezing over of the Illinois and Michigan canal and the Desplaines and Illinois rivers had upon their pollution by Chicago sewage. During the period under observation the canal was frozen over fifty-six days and the rivers about fifty days.

Soon after the canal was frozen over there was an increase of the pollution at Joliet compared with the observations made last summer, and on the 9th of December it was observed at Ottawa where none was found when the examinations were made in June, July and August. The pollution continued to increase until the maximum was reached on the 27th of December at Joliet, and about January 4 at Ottawa. This increase, however, was not alone owing to the ice and low temperature, but the fact that an accident occurred at the pumping works at Bridgeport, while they were being tested before acceptance from the contractors by the city, so that practically, no water was pumped from December 7 to 27, inclusive, as shown by an examination of the following table, giving the difference in depth in the canal and Chicago river.

During this period, when the canal was not frozen over, only about 17,000 cubic feet ot water per minute passed through by gravity, and when frozen over only about 15,000 cubic feet.

On the afternoon of December 27, the pumps were set in motion, and until the end of January about 50,000 cubic feet per minute was pumped from the south branch of the Chicago river into the canal. There was a marked decrease of organic matter in the water at Joliet on January 1. This decrease continued until the end of the month when the quantity of organic matter was less than at any time for the seven months previous. From January 4 to the end of the month there was also a marked decrease of organic matter at Ottawa.

At Peoria a small amount of sewage was observed on January 8; this increased until the 23d, but entirely disappeared on the 29th.

It has been estimated that it takes water from Lake Michigan to reach Peoria—when at a low stage—about twenty-five days. With the ice covering during the period under investigation the pollution by Chicago sewage was not manifest at Peoria until about thirty days after the pumping ceased early in December. This was no doubt partially owing to the fact that during December only 1.76 inches of rain fell, and of this .90 of an inch was snow, practically having no effect in increasing the quantity of water in the Desplaines and Illinois rivers. The pollution disappeared from Peoria in about twenty-one days f.om the time it was first noticed. This latter effect was no doubt largely owing to the result of the increased velocity caused by the pumping of 50,000 cubic feet of water per minute from the 27th of December to the last of January. This is probably the first time since the construction of the pumping-works that Chicago sewage has reached Peoria. On January 11, 1.37 inches of rain fell, and lhis, in addition to the melting snow, caused freshets in some of the tributaries of the Desplaines and Illinois rivers and no doubt affected the chemical determinations of the samples of water collected at Joliet, Ottawa and Peoria on that day.

The following table gives the averages of the analyses of the different samples collected at each place on the same day:

| Places. | Free Ammonia. | Albuminoid Ammonia. | Oxygen used. |
|---|---|---|---|
| | In 1,000,000 parts. | | |
| Bridgeport | 9.7 | 3.7 | 22.4 |
| Joliet, 33 miles below | 6.5 | 2.2 | 11.3 |
| Ottawa, 81 miles below | 4.7 | .75 | 9.0 |
| Peoria, 159 miles below | 1.7 | .43 | 6.45 |

The result of these observations shows that, with the canal covered over by ice, oxidation was returded in the proportion indicated by the smaller losses of 32 per cent. of free ammonia, 40 per cent. of albuminoid ammonia, and 50 per cent. of oxygen used—as compared with the losses shown under the exceptional conditions which obtained in the previous summer. A more nearly accurate conclusion may be reached by a study of the following tables which give the means of 347 analyses embracing eight determinations instead of only three as in the foregoing investigations. These means are grouped for the summer and winter work respectively with the same purpose of exhibiting the effect of low temperature and ice cover excluding free atmospheric effect and retarding flow.

MEANS OF ANALYSES—MAY TO OCTOBER INCLUSIVE, 1888.

| Places. | Number of Analyses.... | Total Solids... | Suspended Matter...... | Nitrogen in Nitrates..... | Chlorine...... | Hardness $CaCO_3$...... | Free Ammonia. | Alb. Ammonia. | Oxygen consumed...... |
|---|---|---|---|---|---|---|---|---|---|
| Bridgeport................ | 29 | 471.2 | 129.20 | .000 | 46.811 | 201.3 | 12.253 | 2.558 | 23.113 |
| Lockport................ | 24 | 431.2 | 69.80 | .000 | 46.120 | 207.7 | 10.882 | 1.990 | 16.230 |
| Joliet.................... | 26 | 442.7 | 107.90 | .000 | 43.658 | 216.8 | 8.932 | 1.681 | 14.301 |
| Morris.................... | 24 | 355.9 | 30.85 | .380 | 32.149 | 214.8 | 4.107 | .707 | 10.920 |
| LaSalle.................... | 23 | 345.7 | 50.30 | 1.037 | 19.717 | 211.7 | .636 | .526 | 8.558 |
| Henry .................... | 19 | 306.0 | 27.50 | .683 | 17.660 | 204.4 | .467 | .481 | 8.657 |
| Peoria.................... | 19 | 329.75 | 54.27 | .8915 | 12.358 | 199.7 | .210 | .522 | 9.769 |
| Pekin..................... | 16 | 353.0 | 84.30 | .795 | 16.152 | 204.6 | .645 | .650 | 9.410 |
| Havana.................... | 25 | 301.78 | 45.4 | .731 | 11.583 | 204.2 | .342 | .430 | 8.142 |
| Beardstown.............. | 24 | 390.0 | 84.7 | .62 | 7.524 | 204.9 | .202 | .380 | 7.354 |
| Grafton.................. | 12 | 301.6 | 50.3 | .582 | 9.205 | 242.4 | .095 | .483 | 7.300 |
| Alton...................... | 15 | 278.6 | 75.2 | ........ | 4.083 | 169.4 | .166 | .356 | 7.356 |

MEANS OF ANALYSES MADE DURING 1889.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Bridgeport................ | 9 | 375.6 | 27.2 | 0.00 | 62.934 | ........ | 8.925 | 2.806 | 26.502 |
| Lockport.................. | 8 | 408.6 | 24.6 | 0.00 | 56.083 | ........ | 8.149 | 2.489 | 22.820 |
| Joliet (Dam 2)............ | 8 | 432.8 | 55.5 | 0.00 | 57.717 | ........ | 8.488 | 2.666 | 21.717 |
| Morris..................... | 8 | 325.2 | 29.1 | 0.00 | 28.748 | ........ | 4.716 | 1.587 | 10.696 |
| LaSalle .................. | 9 | 417.6 | 93.8 | .942 | 13.105 | ........ | 1.456 | .637 | 8.582 |
| Henry..................... | 5 | 316.0 | 30.9 | .962 | 11.691 | ........ | 1.059 | .404 | 8.626 |
| Peoria (Upper Bridge). | 6 | 331.0 | 26.9 | .510 | 12.860 | ........ | 1.637 | .549 | 9.611 |
| Pekin..................... | 6 | 352.0 | 43.5 | 1.259 | 11.792 | ........ | 1.591 | 1.015 | 13.358 |
| Havana.................... | 9 | 354.4 | 80.8 | .414 | 9.277 | ........ | 1.078 | .585 | 9.234 |
| Beardstown.............. | 6 | 317.8 | 56.3 | .966 | 6.933 | ........ | .762 | .357 | 5.505 |
| Grafton................... | 9 | 410.8 | 44.6 | .087 | *7.523 | ........ | .875 | .722 | 9.818 |
| Alton ..................... | 8 | 309.9 | 61.3 | .317 | 5.834 | ........ | .422 | .396 | 7.562 |

The necessary careful study of these data, with due consideration of the numerous factors, has not been practicable in the period which has elapsed since the last samples of water were collected—March 11, 1889. What results may be obtained and what new light thrown upon the problem can be partly inferred from the following discussion, which illustrates the generalization made on a preceding page, to-wit, that the aggregate of organic matter furnished by the tributaries of the Illinois river in their natural condition may greatly exceed the aggregate furnished by the population of their respective watersheds, or than the aggregate which passes Joliet in the canal and Desplaines river.

The volume of water passing LaSalle for about eight weeks in May, June and July would average about ten times that passing Joliet, or 480,000 cubic feet per minute. Of this, about five parts come from the Kankakee, or would show analyses similar thereto, and about four parts would be similarly ascribed

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* This is the mean of 10 determinations—excluding those of January 14 and 21 for the reasons assigned by the chemist in his report.—See Appendix, p. 28.

to the Fox. The following table gives the mean results of the analyses for Joliet, the Kankakee, the Fox, and the Illinois at LaSalle:

| | Chlorine.... | Free Ammonia..... | Albuminoid Ammonia.. | Oxygen Consumed.. | Number.... | Relative Volume...... | |
|---|---|---|---|---|---|---|---|
| Joliet.................. | 45.52 | 9.30 | 1.39 | 13.77 | 9 | 1 | Desplaines river............ |
| Wilmington........... | 1.36 | 0.08 | 0.59 | 14.43 | 7 | 5 | Kpnkakee river.............. |
| Ottawa................. | 4.24 | 0.12 | 0.47 | 6.84 | 8 | 4 | Fox river..................... |
| LaSalle................. | 8.57 | 0.15 | 0.46 | 9.61 | 8 | 10 | Illinois river................... |
| Aggregate............ | 69.39 | 10.20 | 6.26 | 113.18 | .... | 10 | Weight proportioned to |
| LaSalle................ | 86.15 | 1.47 | 4.62 | 96.10 | .... | 10 | volume.................. |
| | —15.76 | 8.73 | 1.64 | 17.08 | .... | ...... | Absolute loss............... |

A brief study of this table leads to very important conclusions. The analyses only give percentages, or density, and the result must be multiplied by the volume flowing, in order to obtain the absolute amounts passing any given point. The oxygen consumed represents the percentage of readily decomposable matter. It is apparent that the amount of organic matter coming from the Kankakee is more than five times that passing Joliet. In like manner, we find that the amount contributed by the Fox is more than twice, and, for the watershed above LaSalle, over seven times that passing Joliet.

The analyses from the Kankakee show an increase in organic matter in high water, so that the mean results for the six months shown in the detritus table (see appendix) should be less than that for the year. The mean discharge for the Kankakee for the entire year is probably 300,000 cubic feet per minute, so that the aggregate organic matter contributed is probably six to seven times that passing Joliet. The mean discharge for the basin above LaSalle is about 700,000 cubic feet per minute. Considering the analyses of the Fox and Big Vermilion, it would appear that the organic matter brought in by land-water is ten to twelve times that passing Joliet. These results can be stated with far more accuracy when the hydrographical work is completed.

Referring again to the table, the line noted as "aggregate" shows the absolute amounts, as compared to that at Joliet, found by multiplying the amounts given for Wilmington and Ottawa by the relative volume, as given in the last column, and adding the result to Joliet. The oxygen determination we have already discussed. The albuminoid ammonia is assumed to measure the nitrogenous matter, or that which is regarded as especially obnoxious. It will be perceived that the contribution coming in with the land-water is over 3½ times that passing Joliet. The absolute amount of chlorine has increased. This is a fixed substance, increasing steadily with the amount of animal wastes, and perhaps by the leaching of salt from the land or from springs.

If the LaSalle determination be multiplied by ten, the relative volume at that point, it will show the absolute amounts. These show a decrease, or that the absolute loss of organic impurities is greater than the total amount passing Joliet. In other words, notwithstanding the contribution passing Joliet, by the time LaSalle is reached the aggregate organic matter is less than the aggregate furnished by the several tributaries as they reach the Illinois valley.

The following table is entirely similar to the preceding, but gives the results of eight weeks of low water in the latter part of July and in August and September. The volume passing LaSalle was about 96,000 cubic feet per minute, or double that reaching Joliet from Chicago. Of the land-water, one-half came from sources that would give analyses similar to the Kankakee, and the other half is represented by the Fox:

| | Chlorine | Free Ammo. | Alb. Ammo. | Oxygen Cons'md | No. | Relative Value. | |
|---|---|---|---|---|---|---|---|
| Joliet | 39.87 | 8.63 | 1.72 | 12.39 | 10 | 1 | Desplaines river |
| Wilmington | 0.64 | 0.14 | 0.56 | 10.95 | 9 | ½ | Kankakee river |
| Ottawa | 6.36 | 0.10 | 0.45 | 5.90 | 7 | ½ | Fox river |
| LaSallle | 22.13 | 0.27 | 0.55 | 8.34 | 8 | 2 | Illinois river |
| Aggregate | 43.39 | 8.75 | 2.22 | 20.77 | ...... | 2 | Weight proportioed to volume |
| LaSalle | 44.26 | 0.54 | 1.10 | 16.68 | ...... | 2 | |
| | —0.87 | 8.21 | 1.12 | 4.09 | ...... | .......... | Absolute loss |

If this table be compared with the preceding it will be seen that the proportion of organic matter is greatest in the higher stages of the river. It will be also apparent that the proportion of nitrogenous matters as shown by the albuminoids and the chlorine is greatest at low water. The absolute loss in organic matter, as shown by the La Salle analyses, is about 20 per cent. as compared to about 17 in the preceding table; and in albuminoid ammonia, some 50 per cent., as compared to about 26 per cent. The absolute amount of decomposition is, of course, much less, but also much greater in proportion to volume of water.

So far as a chemical valuation is concerned, it is apparent that two or three times the water at Joliet would give a stream containing a less proportion of organic matter than the most of the tributaries of the Illinois. If Bridgeport be the point compared, it would take four or five times. Any such statements must, however, be qualified, as the sewage would come in a less decomposed condition, and it is impracticable at this time to say what proportion of water removing the sewage promptly from Chicago would be required, so that the stream shall not contain a greater proportion of organic matter than exists from the natural conditions. All that need be said is that the analyses seem to imply the possibility of reaching this standard.

It must be remembered, however, that the constitution of this matter is different in many respects from that derived from the land, being more largely of animal origin and far more readily decomposed. For this reason it purifies much faster than the land water; in other words, the organic matter does not travel so far in the stream as that of more purely vegetable origin derived from the land. For this reason, also, a larger proportion of dilution is demanded in order to furnish the supply of oxygen for the more rapid decomposition. And for this reason, also, the chemical tests of water from the lower Illinois are likely to show more favorably when a large supply of water is turned in from Lake Michigan than under their natural conditions.

The land waters are already taxed to dispose of the organic matters contained therein, and to this extent are not available for sewage dilution. The analyses show that the waters of Lake Michigan contain only from one-sixth to one-twelfth the organic impurities contained in the waters of the Illinois and its tributaries. The freedom from organic matter and the high percentage of dissolved oxygen prëeminently fit lake water for the dilution of sewage, and it is far more effective for this purpose than any land water from the Illinois watershed.

As to pronouncing definitely at this stage of the investigation upon the one best remedy for existing pollution or recommending the adoption of any specific plan proposed—that is not now warranted. Although the work thus far done under the direction of the State Board of Health is sufficient to determine the general principles of the solution of the drainage problem of Chicago much remains to be done by that city itself before the value and importance of some of the factors can be fixed with scientific accuracy. The actual sewage product of the metropolitan area now tributary to the Illinois and Michigan canal and thence to the Desplaines and Illinois rivers is not yet known—it is only a matter of rough estimate. It is reasonably certain that this estimate is over rather than under the actual amount; but any plans based upon mere estimates are subject to revision in practice, and such revision may involve serious modification.

Furthermore, it is not yet known, from any investigation made by the Chicago Drainage Commission, what the rate of sewage decomposition really is in the sewers themselves before the sewage is discharged into the stream; nor what changes in the density of the drainage pumped at Bridgeport will be produced by establishing a circulation in the south fork at the stock yards. Chicago should at once set about the work of gauging the sewer flow and the determination of the rate of sewage decomposition both within the sewers and in her river and branches, and should complete the special study of the south fork already begun under the Commission. When these data have been added

to the information previously acquired, it will remain to di
and interpret the facts as the basis for the final plans and
mates.

The work done under the direction of the State Board for
Illinois river basin, outside of Chicago proper, and that don
connection with the water supplies of cities and towns an
state institutions has already reached this stage. Substanti
all the data necessary to the intelligent treatment of the p
lems involved in the improvement of the water supplies an
the prevention or limitation of river pollution have been
cumulated. There is required some further investigation, ma
local, of the hydrography of the basin and, very probably, s
additional analyses to clear up a few moot points raised
abnormal determinations in some of the analyses already m
will be necessary.

With these additions the material for a final report on
water supplies of two-thirds of the State, and the sanit
problems of the drainage of its most important river basi
ready for use, and it is purposed to push the work thereon
all practicable dispatch.

# CHEMICAL INVESTIGATIONS

OF THE

# WATER SUPPLIES OF ILLINOIS, 1888-89.

Made by Prof. J. H. Long,

## Under the Direction of the Illinois State Board of Health.

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The following report embraces the preliminary results of the analyses of over 750 samples of water collected by the State Board of Health between May 1, 1888, and March 15, 1889, at Chicago (Lake Michigan); Bridgeport, Lockport and Joliet (Illinois and Michigan Canal); Morris, Ottawa, LaSalle, Henry, Peoria, Pekin, Copperas Creek, Havana, Pearl, Beardstown and near Grafton (Illinois river); Channahon, Wilmington, Ottawa, LaSalle and Chandlerville (from tributaries of the Illinois river); East Dubuque, Rock Island, Quincy, Alton, East St. Louis, St. Louis, Chester and Cairo (Mississippi river), and from smaller streams and supplies to towns and public institutions at Decatur, Kankakee, Galesburg, Elkville, Lincoln, Jacksonville, Pontiac, Elkhart, Springfield, Belleville, Aurora, Cairo, Joliet, Chester, Bunker Hill, Elgin, Freeport, Galena, Danville, Anna, Marseilles, Monticello, Morrison, Bloomington and Normal.

Over 650 of these tests were made between May 1 and November 15, and about 100 between January 14 and March 15,—those latter chiefly of waters of the Illinois river.

Of each water, a two-gallon sample was collected according to the following directions, which were printed on the back of the shipping tags furnished to each collector:

"Clean the jug thoroughly as follows: Fill with water and allow to stand a day or more; pour out most of the water, add some clean sand and shake thoroughly, to reremove anything adhering to the walls of the vessel, then rinse out the sand and fill and rinse several times with water similar to that to be sent. Finally, fill with the water (leaving air space) and close with a good close cork. Tie this down with a piece of strong muslin."

The samples were forwarded to me at 40 Dearborn street, Chicago, and were numbered immediately in the order in which they were received. The chemical examinations were begun as soon as possible, and those constituents liable to change by standing were determined first.

Of the large number of samples sent, but two or three were lost by breakage of jugs or other accident. In a few cases the tests gave evidence that the jugs had not been properly cleansed, and in several other instances the amount sent was too small for all the tests.

On the whole, however, I believe the samples were properly taken and very promptly forwarded. They were delivered to me by the express companies in Chicago without delay.

In the work of analysis I have been ably assisted by Mr. Mark Powers, Mr. J. J. Link and Mr. C. E. Linebarger, to whom my sincere thanks are due.

## METHODS OF ANALYSIS.

Many volumes have been written on the subject of water analysis, and while difference of opinion exists regarding the determination of the ordinary mineral stituents of a water, there is still much discussion as to what tests are best to amount and nature of the organic matters present; in other words, to measure substances on whose presence or absence the value of a water for household purp depends.

Formerly the difficulty of the subject was not recognized as clearly as at present, chemists were accustomed to furnish very exact figures for the amount of organic ter in a water. For a time it was customary, I might almost say *fashionable*, to organic matter as crenic or apocrenic acid, and to several places of decimals. In cases the amount of this organic matter was measured only by loss on ignition residue left on evaporation.

But chemists now recognize that the organic matter in water is usually of very riable and complex nature, consisting of products of which we, in many cases, absolutely nothing.

It is known that certain organic matters, which may find their way into water, capable of producing a great deal of mischief when taken into the stomach, small amount; while it is just as certainly known that other organic matters present in drinking water in much larger amount and still be comparatively harmless. Unfortunately, to distinguish between these different kinds of organic matter in a is a problem of great practical difficulty, as the *absolute* amount present is quite small, and in a state of gradual change. But since the complex and variable ture of this organic matter has been admitted chemists have ceased to try to estimate it as a whole, but have turned their attention to the detection and measurement of tain derived products and to certain empirical reactions which experience shows acterize good or bad waters.

It is on the subject of the value of these empirical tests that great differences opinion exist. The present investigation was undertaken to determine the general acter of a large number of samples, some of which were supposed to be good, some bad, while of many the condition remained to be found by the tests. A good portion of work consisted in a study of the Illinois river and its tributaries, the object of this ing to show the influence of the Chicago sewage poured in at the source of the and to determine, if possible, the rate of destruction of this polluting matter flowing water.

During the latter part of the season the question of supply to the state institu was taken up, it being thought desirable to determine the general character of waters, many of which had never before been examined.

In no case was a full mineral analysis thought necessary, consequently the was confined to such tests as show the main features of the water and its hy value. I believe, in the present state of our knowledge, this information can be given by the following determinations:

- Total solids by evaporation.
- Suspended matters.
- Chlorine.
- Nitrogen in nitrates and nitrites.
- Hardness.
- Free ammonia.
- Albuminoid ammonia.
- Oxygen consumption.

Because of the interest shown by physicians and sanitarians throughout the state this investigation I think it proper to explain somewhat fully the methods employed the various tests.

### TOTAL SOLIDS.

Many of the waters received were very turbid. It was therefore necessary observe great care in withdrawing uniform portions for analysis. The jugs

roughly shaken and then without delay a liter or half a liter was poured out for the t. The solids in this portion were determined by evaporating in a platinum dish on water bath, the bath being large enough to accommodate six of these dishes, holding cubic centimeters at one time. On the completion of the evaporation the dishes re transferred to an air oven kept at a temperature of 110° C. and left there for half an r. They were then cooled quickly and weighed. Subtracting from this weight the wn weight of the dish the solid contents were found. When one liter of water was porated the weight in milligrams was taken as the number of parts per 1,000,000, as specific gravity could be practically taken in most cases as unity.

### SUSPENDED MATTER.

After pouring out the water for solids the jug was again thoroughly shaken and ther portion of one liter was measured out in a flask and transferred to a tall beaker. s was covered and allowed to stand several days until the solids in suspension had npletely settled. Most of the clear liquid was then poured off and the residue, with sediment in the bottom of the beaker, was filtered on a Gooch filter, the last porns being washed out with distilled water. This filter renders most excellent service e; many waters which certainly could not have been filtered clear through paper re successfully filtered through asbestos with this appliance.

The filter and contents were dried at 110° C., as before and weighed. The difference ween this weight and the former gives the weight of solids in solution, supposing same volume of water taken for each test.

### CHLORINE.

For the chlorine test three liters was the amount usually taken. This was evapord to a small volume in a porcelain dish. The residue was treated with a slight exs of pure nitric acid and filtered. In the filtrate the chlorine was found by the Vold method, using a deci-normal solution of silver nitrate and equivalent solution of monium sulphocyanide.

In a few cases less than three liters was taken for the chlorine test. In the samples m the canal at Bridgeport, Lockport and Joliet one liter, or less, was usually suffint, and in several of the artesian waters 100 cubic centimeters was found enough for ect titration without concentration.

### NITROGEN IN NITRATES AND NITRITES.

The value of a determination of nitrates and nitrites in drinking water has long been exed question, and, unfortunately, different chemists hold widely different views on subject. By some the test is held to be of the highest importance, while others k upon it as of no use whatever. As is very often the case a middle course seems best one to take here. Nitrates and nitrites of a water come from the final oxidan of nitrogenous organic matter in it, and thus serve as an indication of past conination. These final products of oxidation are perfectly harmless in themselves, and fact a great many waters containing them can be safely used. This is especially true very deep wells where they are nearly always present. In shallow wells, however, y must always create suspicion, as other matters originally associated with what ve rise to them may not have been so fully oxidized.

There are several methods by which the nitrogen of nitrates can be estimated in ter. In one of these—the Marx method—the water is evaporated to a small bulk and ated with an excess of pure strong sulphuric acid. To the hot mixture a solution ndigo is added as long as the color is destroyed, indigo in sulphuric acid being comtely decomposed by nitric acid.

If the strength of the indigo solution had been previously found by treating a known ate solution (of saltpeter, for instance) in the same way, the volume used by the er residue becomes a measure of the nitrate in it. The method gives good results ong as certain precautions, chiefly suggested by Warington, are followed. But with se precautions it is pretty slow and could not be well applied in this investigation.

Another method is based on the fact that the nitrogen of nitrates in alkaline solution is readily converted into ammonia by action of nascent hydrogen. To apply this to water a definite quantity is evaporated to a small bulk and transferred to a small flask or bulb. A combination of metals known as the zinc-copper couple is added and distillation begun. The zinc and copper act as an electrical pair and liberate hydrogen. This reduces the nitrates or nitrites to ammonia which is distil'ed off and treated as will be explained below.

Sometimes the water residue is rendered strongly alkaline with pure sodium hydrate solution, and then a piece of aluminium foil is added. This dissolves in the alkali with liberation of hydrogen, which reduces the nitrates, as before.

These methods are not quite as convenient or accurate as another one which I followed in all the tests carried out. When a solution of a nitrate is made strongly acid with pure, strong sulphuric acid and brought in contact with certain metals, nitrogen dioxide is produced by decomposition. When the gas is collected without loss it becomes a measure of the amount of nitrate decomposed. This method has been applied to water analysis by Frankland, Warington, and others. In using it, I proceeded in this way: After weighing the residue from the determination of total solids, I treated it with a little pure water to dissolve all that was soluble. The liquid was filtered into a small beaker, the insoluble part being washed with several small portions of pure water. The contents of the beaker were then reduced to a small bulk—two or three cubic centimeters—by evaporation on a water bath, and transferred to a Lunge nitrometer containing mercury. Twice the volume of pure, strong sulphuric acid was then introduced and the mixture shaken, gently at first and then vigorously. This brings the mercury in contact with the liberated nitric acid, if any is present, decomposing it to nitrogen dioxide. After the gas cools by standing, its volume can be measured and reduced to corresponding weight. The nitrometer employed had a capacity of 50 cubic centimeters. In a few cases it was found necessary to repeat the experiment, as the volume of water taken gave more nitrogen dioxide gas than could be measured.

HARDNESS.

The hardness of a water is usually measured by its soap-destroying power. In every case I found it by means of a standard soap solution, of which one cubic centimeter precipitated the equivalent of one milligram of calcium carbonate.

In the river waters, 100 cubic centimeters was the amount taken for the test and soap solution was added until, after thorough shaking, a permanent lather was obtained. In the case of some of the well waters, 50, 25 or even 10 cubic centimeters, diluted to 100 with distilled water, was found, by a preliminary trial, to be the right amount to take. The soap solution was made by dissolving about 10 grams of good castile soap in a liter of weak alcohol, and adjusted by comparing with a standard lime solution made by dissolving 1 gram of pure calcium carbonate in hydrochloric acid, evaporating to dryness and dissolving in water to make a liter.

The soap solution was diluted so that 11 cubic centimeters were required to give a permanent lather, with 10 cubic centimeters of the lime solution diluted to 100. Allowing 1 cubic centimeter for the amount necessary to form a lather with pure water, the remaining 10 cubic centimeters just precipitate the equivalent of 10 milligrams of calcium carbonate. It is difficult to obtain constant or regular results with this test in waters containing much suspended or organic matter. It was not employed in the examination of the last 100 samples.

FREE AMMONIA.

The determination of free ammonia in a water is often of the greatest value. As a general thing it represents one of the last stages in the decomposition of nitrogenous organic matter, and its amount is sometimes a rough measure of what has been decomposed. It must be remembered, however, that this free ammonia is perfectly harmless in itself, in the amount in which it occurs in water, and often when very abundant cannot be taken as an indication of any present or even very recent contamination. In river or shallow well waters it points to a decay of nitrogenous organic matter, not removed, and may be accompanied by some of this matter in a much less advanced

stage of oxidation. In most artesian well waters, free ammonia appears abundantly, and generally unaccompanied by organic matter except in very minute amount. Hence, the conclusion drawn from the free ammonia found in a sample of water depends largely on the source of the latter.

The test is carried out as follows: 500 cubic centimeters of the water, or in bad cases 10, 25 or 50 cubic centimeters diluted to 500 with pure distilled water quite free from ammonia, is poured into a carefully cleansed retort connected with a long Liebig's condenser. About 5 cubic centimeters of pure strong sodium-carbonate solution and a small amount (half a gram) of coarsely powdered and freshly ignited pumice stone are added to the contents of the retort, which is then warmed by means of a water bath. After about ten minutes the latter is removed, the retort dried, and then heated directly by a Bunsen burner until distillation begins. By the preliminary warming on the water bath the chief danger of cracking the retort with the lamp is avoided. Bumping in the boiling liquid is completely prevented by the addition of the pumice stone. The heat must be so regulated that the distillation proceeds rather slowly, about 50 cubic centimeters in 15 minutes being a good rate. In the presence of sodium carbonate the free ammonia is readily driven off with the steam, which must be condensed in the Liebig apparatus by a good current of cold water. The distillate, collected in four portions of 50 cubic centimeters each, contains practically all the free ammonia, and it remains to measure its amount.

The distillate is caught directly in four tubes of exactly the same size, made of clear thin glass with a mark to indicate the 50 cubic centimeters. To each tube 2 cubic centimeters of Nessler solution is added. The Nessler reagent is a solution which has the property of striking a deep yellowish brown color with weak ammonia solutions, the depth of shade depending on the amount of ammonia present.

The first of the above named tubes should show much the deepest color, the second and third less, while the fourth should be practically without color. If it is not, another 50 cubic centimeters should be collected and tested in the same way. The amount of ammonia in each one of these tubes is estimated by duplicating the shade by means of ammonia solutions of known strength. For this purpose a standard ammonium chloride solution is prepared which contains the equivalent of .01 milligram of ammonia in each cubic centimeter. Definite volumes of this are diluted to 50 cubic centimeters with pure distilled water, and then treated with the Nessler reagent. In this way a series of colors is obtained indicating certain small amounts of ammonia in 50 cubic centimeters, and by making a number of tests those obtained from the four or five distillates can be exactly duplicated. The known ammonia in the duplicates shows immediately the amount in the distillates or, in other words, in the volume of water taken.

### ALBUMINOID AMMONIA.

This is a name given by Wanklyn to ammonia produced by distillation of nitrogenous organic bodies with a strong oxidizing solution of potassium permanganate and potassium hydrate. Many organic matters distilled with this solution are decomposed, giving up their nitrogen in the form of ammonia, and this is called albuminoid ammonia because albuminous bodies are types of those readily decomposed in this way. Albuminoid ammonia, then, does not exist already formed in a water but is produced from it by the laboratory process through the rapid oxidation of the complex matters it contains. If these matters were allowed to decompose spontaneously they would give rise to free ammonia in time which could be detected by the test given above.

We can, therefore, look upon the laboratory oxidation as a substitute for the slow, natural oxidation, although it is not probable that exactly the same amounts of ammonia are in any case formed by the two processes from similar materials.

To understand the meaning and value of the indications given by this test, it is necessary to consider what takes place when albuminous or similar substances undergo spontaneous decomposition. Unfortunately, many of the steps in such decompositions are obscure, but it is known that among the products found we have at some stage indol, skatol, leucine, tyrosine, aspartic acid, peptone, various fatty acids,

and other bodies of the aromatic group. Ordinary sewage added to watery solutions of albuminous bodies is an excellent agent to bring about most of these decompositions.

The products named have generally definite composition, and often crystalline structure so that they can readily be obtained in condition for exact investigation. Such investigations, as carried out by Tiemann and Preusse, for instance, have shown that the nitrogenous products in the above list give up practically the whole of their nitrogen as ammonia when distilled with the oxidizing solution.

It is now well known, although formerly a different view was held, that *fresh* albuminous or similar substances are not completely decomposed in this manner.

The intensity of the reaction, therefore, which the chemist obtains by application of the albuminoid ammonia test to a water contaminated with these complex nitrogenous matters, depends largely on their state of preservation, in other words on time and temperature, as both are important factors in producing decomposition.

Another very important contamination in waters to which sewage has access, is urea. Wanklyn states that this substance yields no ammonia by the albuminoid process, while other chemists show that a portion of its nitrogen is given off in this manner. Tiemann's experiments indicate that all the nitrogen may be obtained in this way.

My own experiments indicate that with strong permanganate solutions the urea is rapidly decomposed, giving off most of its nitrogen in the form of ammonia. If, in the purification of the permanganate by long boiling, a portion is changed to manganate, the decomposition of the urea is slow and much less perfect.

Hair, wool and gelatinous substances contain matter similar to albumin in composition, and are decomposed in the same general way, but not as readily.

Faecal matter consists of undigested food, containing more or less substance of albuminous nature along with products of its decomposition, as indol and skatol. Also mucus, epithelium, biliary products and numerous substances in small amount, about which little is known. The nitrogenous portions of this matter can be classed with those already mentioned which are decomposed wholly or partially with evoluti n of ammonia by the alkaline permanganate solution.

The determination of albuminoid ammonia, then, gives us a rough measure of the amoun of readily decomposable nitrogenou matter a water may contain, and to be of value, should be s udied in connection with the source of the water, its temperature and distance from possible contamination.

Practically the test is carried out in this way: To the residue left in the retort after the distillation of the free ammonia 50 cubic centimeters of the permanganate solution is added. This is prepared by dissolving 9 grams of purest potassium permanganate in distilled water and adding 225 grams of good potassium hydrate and enough water to make 1,500 cubic centimeters in all. The solution is then boiled down to 1,000 cubic centimeters in order to free it from ammon a. With the grade of potassium hydrate employed I find no difficulty in making a good solution in this way.

After adding the alkaline permanganate the distillation is begun again and four more portions of 50 cubic centimeters each boiled over. These are tested exactly as before. In some cases it is necessary to continue the distillation even further to secure all the ammonia.

A fuller discussion of some of the points of this process will be found below where I explain the results obtained by the actual tests.

## OXIDATION TESTS.

Early in the history of sanitary water analysis, attempts were made to measure organic matter present by the amount of oxygen it consumed under certain conditions. Forchammer first proposed to accomplish this by treating the water with a dilute solution of potassium permanganate as long as its color was destroyed, but this plan gave only crude results. Much better results are reached by several modifications of this process, notably by that of Kubel. In this the oxidized water is boiled with an excess of dilute permanganate solution for a definite time, after which the amount of the oxidizing salt not acted on is found by means of oxalic acid.

The solutions required are:

Potassium permanganate, 320 milligrams in 1 liter.

Oxalic acid, 630 milligrams in 1 liter.

Sulphuric acid, 2 volumes of strong *pure* acid to 1 of water.

The acid and permanganate solutions are exactly equivalent to each other; that is, the permanganate is decolorized by an equal volume of the other.

To make the test 100 cubic centimeters of the water are measured into a clean beaker, 5 cubic centimeters of the acid and 10 of the permanganate are added, after which the solution is quickly brought to the boiling point and boiled five minutes. If the color is all destroyed a new trial must be made, using 20 or even 30 cubic centimeters of the permanganate in some cases.

At the boiling temperature a part of the permanganate is decomposed, giving up its oxygen to the organic matter in the water. At the end of the five minutes the amount of the salt not decomposed is found by use of the oxalic acid solution. This could be accomplished by adding the latter to the hot liquid in the beaker until the color is just destroyed and noting the volume required for this; but it can be more accurately done by adding at once 10 cubic centimeters of the oxalic acid, which destroys all the color; then add, drop by drop, the permanganate until a trace of pink color just reappears. Subtracting 10 cubic centimeters from the total volume of permanganate used we have that required for the organic matter. Each cubic centimeter so used gives up .08 milligrams of oxygen, which is commonly referred to as "oxygen consumed." The test is empirical and does not give absolute results. Many organic substances do not seem to be decomposed at all in this way. Urea is one of these and many others suffer only partial decomposition. It has been observed, however, that partially decomposed bodies react more strongly on it than do the substances from which they were originally derived. Fresh white of egg in dilute solution has a much less marked oxygen-consuming power than is shown after the solution begins to putrify. This recalls some peculiarities of the albuminoid-ammonia reaction.

The test tells us nothing about the character of the organic matter which it indicates, and does not distinguish between comparatively harmless vegetable contaminations and more dangerous ones of animal origin. In fact, vegetable matters seem to react very strongly with it, and, besides this, it is affected by nitrites, frequently present in waters, as well as by organic matter.

Notwithstanding these weak points in the method, its results have considerable value, especially when considered in connection with those of other tests, and it frequently aids materially in forming an opinion about a doubtful sample.

With these explanations about methods of analysis, I pass now to a consideration of the results obtained in the actual work.

### LAKE MICHIGAN WATER, CHICAGO.

The water supply of Chicago is taken from Lake Michigan by means of a tunnel running two miles out from the shore line. Nearly 100,000,000 gallons daily are pumped, and work is now in progress on another tunnel, which is to be extended to a point four miles from the shore. This will furnish a greatly increased supply. The general character of the water is shown by the following analysis made in my laboratory a few years ago. The mineral constituents of the water are practically constant. In parts per million, the results obtained were:

| | |
|---|---|
| Calcium sulphate | 5.30 |
| Calcium carbonate | 76.50 |
| Magnesium carbonate | 37.73 |
| Ferrous carbonate | .49 |
| Potassium sulphate | 4.85 |
| Sodium chloride | 3.86 |
| Silica | 5.25 |
| Alumina | traces |
| Phosphates | traces |
| Total mineral constituents | 133.98 |

Table I. gives the results obtained by the weekly examinations made during the summer. The water was taken from a faucet on the second floor of the building, No. 40 Dearborn street. Departures from the general average are unimportant, except on October 2d. This is explained by the fact that, owing to changes in the pumps and for other causes, the shore inlet was frequently employed about that time. The entrance to this inlet is about 1,200 feet from the present shore line, and in comparatively shallow water. When the lake is rough, foreign matter is easily washed into the pipes. The practice of using this short tunnel, except in cases of grave necessity, can not be too strongly condemned.

The total absence of nitrates and nitrites, the very low chlorine, free ammonia and oxygen consumption are important features of this water. The albuminoid ammonia seems to be no greater in water taken from the crib than in that from poin s several miles further out. It is undoubtedly quite constant throughout Lake Michigan.

By comparison with results obtained by Mr. A. W. Smith in examinations of Lake Erie water, at Cleveland, I observe several important differences in the two supplies, which suggests an interesting field of inquiry. The proportion of organic matter in the Lake Michigan water seems to be much less than that in Lake Erie.

TABLE I.—CHICAGO.

| Date. 1888. | | Total Solids... | Suspended matter...... | Nitrogen in Nitrates...... | Chlorine...... | Hardness $CaCO^3$....... | Free Ammonia | Alb. Ammonia | Oxygen consumed...... | Physical Conditions. | *Mean temperature — week ending...... | *Tot'l precipt'n week ending. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| May | 1 | 141.0 | 8.0 | 0.00 | 2.230 | 126.0 | .006 | .064 | 1.44 | Slightly opalescent ... | 53.58 | .72 |
| " | 8 | 148.0 | 14.5 | 0.00 | 2.290 | 126.0 | .010 | .088 | 1.20 | " " ... | 51.75 | 2.04 |
| " | 15 | 143.0 | 7.5 | 0.00 | 2.124 | 126.4 | .005 | .083 | 1.52 | " " ... | 48.43 | .80 |
| " | 22 | 144.5 | 6.6 | 0.00 | 2.230 | 118.8 | .004 | .082 | 1.48 | " " ... | 50.98 | .43 |
| " | 29 | 143.6 | 9.5 | 0.00 | 2.230 | 126.0 | .006 | .087 | 1.12 | " " ... | 61.43 | 2.70 |
| June | 5 | 143.4 | 8.0 | 0.00 | 2.230 | 126.0 | .004 | .088 | 1.52 | Clear ................... | 57.62 | .46 |
| " | 12 | 140.8 | 7.5 | 0.00 | 2.240 | 124.0 | .009 | .093 | 1.40 | " ................... | 63.87 | .03 |
| " | 19 | 147.4 | 9.2 | 0.00 | 2.180 | 125.0 | .010 | .093 | 1.28 | " ................... | 74.94 | .00 |
| " | 26 | 149.2 | 7.4 | 0.00 | 2.680 | 125.0 | .003 | .092 | 1.12 | " ................... | 71.87 | .24 |
| July | 3 | 148.0 | 13.4 | 0.00 | 2.100 | 125.0 | .002 | .070 | 1.12 | " ................... | 68.04 | 1.15 |
| " | 10 | 148.6 | 13.8 | 0.00 | 2.332 | 125.0 | .001 | .098 | 1.28 | " ................... | 71.00 | 2.24 |
| " | 17 | 146.7 | 12.2 | 0.00 | 2.003 | 126.0 | .008 | .096 | 1.56 | " ................... | 69.42 | .00 |
| " | 24 | 149.4 | 16.9 | 0.00 | 2.124 | 125.0 | .006 | .094 | 1.52 | " ................... | 71.57 | .29 |
| " | 31 | 136.3 | 6.0 | 0.00 | 2.124 | 124.0 | .002 | .082 | 1.41 | " ................... | 63.42 | 1.04 |
| Aug. | 7 | 139.0 | 6.0 | 0.00 | 1.770 | 125.0 | .006 | .088 | 1.36 | " ................... | 73.45 | 1.29 |
| " | 14 | 146.5 | 11.8 | 0.00 | 1.888 | 125.0 | .010 | .093 | 1.44 | Light floating matter. | 65.35 | .12 |
| " | 21 | 137.2 | 4.0 | 0.00 | 1.832 | 125.0 | .008 | .094 | 1.52 | Clear ................... | 70.64 | .68 |
| " | 28 | 142.5 | 10.5 | 0.00 | 1.416 | 130.0 | .010 | .094 | 1.52 | Slight turbidity ....... | 67.21 | .01 |
| Sept. | 4 | 155.6 | 19.9 | 0.00 | 1.649 | 126.0 | .010 | .095 | 1.44 | " " ........ | 65.57 | .00 |
| " | 11 | 142.1 | 6.7 | 0.00 | 1.295 | 125.0 | .006 | .096 | 1.52 | Clear ................... | 66.93 | .17 |
| " | 18 | 146.8 | 10.3 | 0.00 | 1.770 | 125.0 | .012 | .100 | 1.20 | " ................... | 57.30 | .75 |
| " | 25 | 154.2 | 5.2 | 0.00 | 2.357 | 125.0 | .008 | .104 | 1.44 | Slight turbidity ....... | 60.57 | .06 |
| Oct. | 2 | 382.0 | 227.6 | 0.00 | 1.779 | 127.0 | .013 | .181 | 4.32 | Very turbi !!!........ | 49.50 | .36 |
| " | 9 | 212.0 | 57.5 | 0.00 | 1.888 | 128.0 | .007 | .104 | 1.84 | Slight turbidity ....... | 49.35 | .70 |
| " | 16 | 154.8 | 20.5 | 0.00 | 2.832 | 127.0 | .010 | .094 | 1.44 | Nearly clear ........... | 49.71 | .36 |
| " | 23 | 167.0 | 30.1 | 0.00 | 2.800 | 125.0 | .010 | .076 | 1.60 | S ightly turbid ........ | 42.57 | 1.33 |
| " | 30 | 170.0 | 28.2 | 0.00 | 2.336 | 126.0 | .012 | .070 | 1.60 | Nea ly clear ........... | 49.42 | .20 |
| †Mean.. | | 149.9 | 13.5 | 0.00 | 2.113 | 125.3 | .007 | .089 | 1.42 | | | |

* From a number of points where meteorological observations are systematically recorded, the data of temperature and precipitation (rain or snow) have been obtained. In such cases these factors are added to the statement of Prof. Long's chemical determinations, for the purpose of aiding their interpretation. They help to explain many of the abnormal variations, due to storm water as a local cause of pollution, and also the variations in the rate of sewage oxidation as affected by temperature and dilution.—J. H. R.

† Omitting Oct. 2.

## The Illinois and Michigan Canal—Bridgeport to Joliet.

At Bridgeport about 50,000 cubic feet of water per minute is pumped from the south fork of the Chicago River to feed the Illinois and Michigan Canal.

This water, coming originally from Lake Michigan, is mixed on the way with a large part of the city sewage and with the drainage from the stockyards. The sewage from the city is comparatively dilute, and amounts to about 70,000,000 of gallons daily. I have no very certain data showing its composition at the outlets from the sewers, but during the summer season it is doubtless in an advanced state of decomposition, as indicated by partial tests which I made a few years ago in particular cases.

As regards the decomposition in the river itself, the data are almost as scanty. Tests which I made of the water of the North Branch during April last have some value in this connection. Seven samples were taken near Chicago avenue and analyzed, with these results as regards free and albuminoid ammonia:

| | Per million. Free. | Alb. |
|---|---|---|
| 1 | 4.45 | 2.50 |
| 2 | 6.15 | 1.85 |
| 3 | 5.40 | 2.26 |
| 4 | 6.30 | 3.30 |
| 5 | 6.20 | 3.46 |
| 6 | 5.80 | 3.27 |
| 7 | 6.20 | 2.87 |
| Mean | 5.79 | 2.79 |

Here we have a ratio of 2:1 between free and albuminoid ammonia. Farther north in the stream tests made about the same time gave a relation of nearly 1:1.

At Bridgeport, in the tests made during May, the ratio of 5:1 was usually observed, indicating a larger amount of decomposition in the river itself. It is, perhaps, fair to say that at all times important changes take place in the Chicago River, and that in the summer time many important decompositions are completed here.

The stockyards sewage has been a very important factor in making up the character of the water leaving the Bridgeport pumps. In the summer of 1886 it amounted to about 7,000,000 gallons daily, and gave then by several analyses in parts per 1,000,000:

| | |
|---|---|
| Free ammonia | 42. |
| Albuminoid-ammonia | 6.4 |
| Oxygen consumed | 208. |

Later tests show a great improvement in the character of this water, which is explained by the fact that it has been found commercially profitable to remove many of the contaminating matters to use in fertilizers, etc.

The water collected at Bridgeport was taken at a point 100 feet west of the pumps, and from the center of the channel. During the period of collection the pumps were in continuous operation, discharging about 50,000 cubic feet, or about 370,000 gallons per minute, or in the day about seven times the amount of sewage flowing into the river from all sources. From the 13th to the 19th of September, inclusive, four only of the eight pumps were in operation. Some of the effects of this are shown by the tables.

The results of the analyses are given in Table II. It will be observed that these analyses show peculiar variations from week to week. Many of these variations can not be accounted for as a number of imperfectly understood factors combine to make up the character of the river from day to day. With a high lake level, for instance, less dirty water flows out from the slips and a clearer mixture reaches the pumps. Sudden changes can also be produced by a heavy rain washing out the sewers, or by passage of a large propeller in the river just before a sample was taken in the canal beyond. Each of these causes would agitate the water and bring a mass of filth in suspension.

TABLE II.—BRIDGEPORT.

| Date. 1888. | Total Solids... | Suspended matter...... | Nitrogen in Nitrates...... | Chlorine...... | Hardness $CaCO^3$...... | Free Ammonl. | Alb. Ammonl. | Oxygen consumed...... | Phy-ical Conditions. | Mean Tem. | Total Pr. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| May 1 | 1099.0 | 467.0 | 0.00 | 155.700 | 159.0 | 29.200 | 6.800 | 59.600 | Black and dirty; very bad od[illegible] | | |
| " 8 | 450.0 | 115.1 | 0.00 | 48.140 | 159.0 | 11.120 | 3.700 | 29.600 | Dark with offensive odor...... | | |
| " 15 | 580.0 | 28.5 | 0.00 | 59.470 | 242.4 | 10.760 | 1.800 | 22.200 | Light colored sediment, od[illegible] strong...... | | |
| " 22 | 428.1 | 76.7 | 0.00 | 30.440 | 219.6 | 7.720 | 2.520 | 22.720 | Light colored sediment, [illegible] strong...... | | |
| " 28 | 505.5 | 147.0 | 0.00 | 35.400 | 235.2 | 8.220 | 2.080 | 20.800 | Dark, turbid; strong odor...... | | |
| June 5 | 474.8 | 75.1 | 0.00 | 25.488 | 230.4 | 7.700 | 2.009 | 21.080 | Clearer than usual; odor stro[illegible] | | |
| " 12 | 464.9 | 132.0 | 0.00 | 36.816 | 210.0 | 10.480 | 1.960 | 21.600 | Black; strong odor...... | | |
| " 19 | 347.5 | 62.3 | 0.00 | 21.240 | 174.0 | 7.960 | 2.920 | 19.760 | " " " | | |
| " 26 | 367.0 | 155.2 | 0.00 | 14.160 | 192.0 | 6.120 | 1.720 | 18.560 | Clearer than usual; odo stro[illegible] | | |
| July 6 | 406.8 | 84.8 | 0.00 | 38.232 | 216.0 | 11.240 | 1.200 | 19.600 | Black; strong odor...... | | |
| " 10 | 946.4 | 510.5 | 0.00 | 100.536 | 224.0 | 19.880 | 3.640 | 50.800 | Very filthy...... | | |
| " 17 | 486.5 | 109.7 | 0.00 | 62.304 | 212.0 | 16.800 | 2.760 | 26.320 | Black; strong odor...... | | |
| " 24 | 347.5 | 84.5 | 0.00 | 27.736 | 168.0 | 7.160 | 2.040 | 23.740 | Dark; strong odor...... | | |
| " 31 | 754.9 | 144.5 | 0.00 | 181.248 | 240.0 | 31.040 | 1.840 | 26.560 | Dark; very bad odor...... | | |
| Aug. 7 | 420.3 | 72.5 | 0.00 | 31.152 | 210.0 | 9.800 | 1.800 | 18.000 | Dark; turbid; strong odor...... | | |
| " 14 | 373.0 | 49.8 | 0.00 | 25.488 | 192.0 | 10.600 | 1.610 | 20.000 | " " " " | | |
| " 21 | 323.5 | 50.4 | 0.00 | 25.488 | 190.0 | 7.600 | 3.240 | 15.520 | " " " " | | |
| " 28 | 341.2 | 65.0 | 0.00 | 28.320 | 194.0 | 8.560 | 1.360 | 15.840 | Nearly clear; strong odor...... | | |
| Sept. 4 | 344.7 | 109.6 | 0.00 | 14.160 | 180.0 | 6.480 | 2.840 | 17.120 | Turbid; strong odor...... | | |
| " 11 | 336.8 | 65.5 | 0.00 | 12.744 | 168.0 | 10.400 | 1.880 | 14.000 | Slightly turbid; strong odor...... | | |
| " 14 | 447.0 | 99.0 | 0.00 | 29.736 | 190.0 | 9.760 | 3.320 | 14.560 | Dark sediment; strong odor...... | | |
| " 18 | 583.4 | 184.2 | 0.00 | 76.464 | 210.0 | 25.760 | 2.600 | 15.680 | " " " " | | |
| " 20 | 530.0 | 204.2 | 0.00 | 49.560 | 208.0 | 21.250 | 4.960 | 16.320 | " " " " | | |
| " 25 | 345.0 | 93.0 | 0.00 | 30.444 | 180.0 | 8.760 | 1.780 | 11.200 | Opalescent; strong odor...... | | |
| Oct. 9 | 321.0 | 78.1 | 0.00 | 28.320 | 174.0 | 11.840 | 1.680 | 21.760 | Strong odor; turbid...... | | |
| " 16 | 341.0 | 58.3 | 0.00 | 50.960 | 200.0 | 9.760 | 2.480 | 30.401 | Opalescent; strong odor...... | | |
| " 23 | 415.2 | 83.6 | 0.00 | 61.152 | 240.0 | 9.200 | 2.600 | 37.440 | Very strong odor; dark colored | | |
| " 26 | 499.0 | 182.7 | 0.00 | 42.480 | 210.0 | 13.250 | 2.660 | 15.520 | Very dirty; strong odor...... | | |
| " 30 | 386.8 | 157.5 | 0.00 | 14.160 | 212.0 | 6.920 | 2.400 | 24.000 | Clearer than usual, less odor than usual...... | | |
| Mean . | 471.2 | 129.2 | 0.00 | 46.811 | 201.3 | 12.253 | 2.558 | 23.113 | | | |
| 1889 | | | | | | | | | | | |
| Jan. 14 | 389. | 41 | 0.00 | 49.655 | ...... | 9.560 | 3.480 | 23.680 | N' y cle'r: strong odor | 28.3 | [illegible] |
| " 21 | 363.4 | 24. | 0.00 | 92.580 | ...... | 11.520 | 2.840 | 23.840 | Opalesc'nt: sli'ht odor | 26.1 | [illegible] |
| " 28 | 340.0 | 17. | 0.00 | 35.450 | ...... | 6.000 | 1.680 | 16.480 | N'ly clear; slight odor | 29. | [illegible] |
| Feb. 4 | 313.4 | 14. | 0.00 | 52.038 | ...... | 3.520 | 1.980 | 18.080 | " " " | 28.7 | [illegible] |
| " 11 | 294.0 | 23. | 0.00 | 59.118 | ...... | 3.080 | 1.900 | 20.000 | " " " | 17.2 | [illegible] |
| " 18 | 433.0 | 35.3 | 0.00 | 117.528 | ...... | 17.380 | 5.150 | 46.400 | Slight sed.; str'g odor | 22. | [illegible] |
| " 25 | 355.4 | 16. | 0.00 | 39.648 | ...... | 6.760 | 2.400 | 36.400 | Opalescent; str'g od'r | 6.5 | [illegible] |
| Mar. 4 | 481.0 | 32.8 | 0.00 | 56.640 | ...... | 12.720 | 3.520 | 27.240 | " " " | ...... | ...... |
| " 11 | 420.0 | 41.6 | 0.00 | 63.720 | ...... | 9.760 | 2.300 | 26.400 | " " " | ...... | ...... |
| Mean.. | 376.6 | 27.2 | 0.00 | 62.934 | ...... | 8.925 | 2.806 | 26.502 | | | |

As compared with the results obtained in 1886, these analyses show several remarkable peculiarities. Of course no fair conclusion can be drawn from single tests, but the averages undoubtedly give us a good basis for comparison. We have here, in parts per million, for the summer tests.

Free ammonia......12.253
Alb. ammonia...... 2.558
Oxygen consumed......23.113

which gives 4.8:1 as the ratio of free to albuminoid ammonia.

In 1886 the results obtained gave

Free ammonia......17.44
Albuminoid-ammonia...... 1.195
Oxygen consumed......20.580

with 14.6:1 as the ratio of free to albuminoid ammonia. Taking into consideration the irregularities in the tests of 1886, it is probable that a ratio of 10:1 is fairer than that deduced from the averages for the whole season. Even with this correction there still remains a great difference in the result of the two seasons. But after what has been said above I think it is not necessary to look far for an explanation of this.

I have shown in a former report that the rate of sewage oxidation—using this term in its broad sense—depends very largely on temperature, being most rapid in warm weather. An instructive confirmation of the views advanced then is furnished by the cold weather tests tabulated above.

Here we have the ratio of free to albuminoid ammonia nearly 3:1 with increased oxygen consumption and greatly diminished suspended matter. The marked increase in albuminoid ammonia can not, therefore be charged to this.

It will be remembered that the summer of 1886 was unusually warm and dry, so warm that vastly greater amount of decomposition took place in the Chicago river itself, as shown by repeated observations of the South Branch, than was the case during the summer of 1888. The escape of gaseous products of decomposition was very marked in 1886 in the vicinity of Archer Avenue bridge, and everything indicated that the sewage reached the pumps in a more advanced stage of decomposition than during the period of the observations covered by this report.

While the summer of 1886 was unusually warm and the conditions for putrefactive changes most favorable, it must also be said that the winter of 1889 has been unusually mild, so that we do not obtain an exaggerated view of the effects of temperature changes by comparison. In a colder season the ratio of free to albuminoid ammonia would doubtless be less than 3:1.

LOCKPORT.

The next tests were made at Lockport, 29 miles below Bridgeport. There is no dilution on the way except by rain. The results of the analyses are given in table III.

TABLE III.—LOCKPORT.

| Date. 1888. | | Total Solids... | Suspended matter....... | Nitrogen in Nitrates...... | Chlorine...... | Hardness $CaCo^3$...... | Free Ammonia | Alb. Ammonia | Oxygen consumed....... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|---|
| May | 3 | 538.0 | 41.0 | 0.00 | 77.800 | 279.0 | 15.700 | 3.30 | 25.12 | Very turbid; strong odor........ |
| " | 10 | 608.5 | 242.0 | 0.00 | 21.240 | 183.0 | 8.480 | 2.72 | 24.64 | " " " " ........ |
| " | 17 | 692.0 | 107.0 | 0.00 | 69.920 | 257.2 | 12.800 | 1.56 | 15.92 | Light brown; odor plain......... |
| " | 24 | 468.4 | 56.9 | 0.00 | 35.400 | 260.4 | 6.380 | 1.68 | 17.44 | Milky turbidity; odor strong.... |
| " | 31 | 699.0 | 80.6 | 0.00 | 121.770 | 268.8 | 17.300 | 2.21 | 22.56 | Dark and turbid; bad odor...... |
| June | 7 | 428.1 | 64.5 | 0.00 | 22.650 | 228.0 | 10.120 | 1.76 | 17.24 | Light colored sediment; strong odor.............................. |
| " | 14 | 387.1 | 58.0 | 0.00 | 25.490 | 213.0 | 11.400 | 1.56 | 12.12 | Dark colored; bad odor.......... |
| " | 21 | 322.9 | 46.5 | 0.00 | 28.320 | 192.0 | 7.240 | 1.72 | 15.76 | Dark; strong odor............... |
| " | 27 | 331.9 | 47.0 | 0.00 | 35.400 | 200.0 | 10.500 | 1.70 | 16.00 | Light colored sediment; strong odor.............................. |
| July | 19 | 346.7 | 38.0 | 0.00 | 59.472 | 215.0 | 11.000 | 1.80 | 18.56 | Brownish; odor not strong...... |
| " | 26 | 342.5 | 46.7 | 0.00 | 32.922 | 168.0 | 11.040 | 1.18 | 15.36 | Light colored; odor strong....... |
| Aug. | 3 | 489.5 | 171.4 | 0.00 | 28.320 | 216.0 | 15.040 | 2.02 | 22.40 | " " " " ....... |
| " | 9 | 386.4 | 48.8 | 0.00 | 32.568 | 204.0 | 10.760 | 3.56 | 13.64 | Light colored sediment; strong odor.............................. |
| " | 16 | 312.4 | 31.2 | 0.00 | 12.744 | 188.0 | 6.920 | 1.90 | 14.72 | Light colored sediment; strong odor.............................. |
| " | 23 | 330.5 | 32.5 | 0.00 | 12.704 | 180.0 | 6.640 | 1.68 | 15.28 | Light colored sediment; strong odor.............................. |
| " | 30 | 390.0 | 45.4 | 0.00 | 58.410 | 190.0 | 9.840 | 1.52 | 18.56 | Dark sediment; strong odor..... |
| Sept. | 13 | 348.8 | 30.8 | 0.00 | 15.576 | 168.0 | 9.760 | 1.80 | 15.20 | Opalescent; strong odor......... |
| " | 15 | 423.0 | 39.0 | 0.00 | 49.560 | 180.0 | 11.760 | 2.30 | 12.48 | " " " ......... |
| " | 20 | 607.0 | 143.4 | 0.00 | 87.792 | 250.0 | 19.040 | 2.06 | 10.72 | Dark sediment; strong odor..... |
| " | 27 | 338.8 | 67.0 | 0.00 | 33.984 | 166.0 | 8.800 | 2.60 | 13.44 | Opalescent; strong odor......... |
| Oct. | 12 | 395.4 | 57.1 | 0.00 | 59.470 | 182.0 | 9.440 | 1.86 | 19.60 | Turbid; strong odor.............. |
| " | 18 | 373.6 | 65.8 | 0.00 | 50.965 | 216.0 | 10.960 | 2.28 | 8.80 | Opalescent; strong odor ......... |
| " | 25 | 384.0 | 53.8 | 0.00 | 99.008 | 190.0 | 8.880 | 1.48 | 6.88 | " " " ......... |
| " | 30 | 405.0 | 61.1 | 0.00 | 35.400 | 192.0 | 11.381 | 1.54 | 17.28 | Turbid; strong odor.............. |
| Mean... | | 431.2 | 69.8 | 0.00 | 46.120 | 207.7 | 10.882 | 1.99 | 16.23 | |
| 1889. | | | | | | | | | | |
| Jan. | 14 | 385.4 | 21.0 | 0.00 | 67.260 | ...... | 8.580 | 2.585 | 26.72 | Opalescent; strong odor. ........ |
| " | 21 | 544.0 | ...... | 0.00 | 73.632 | ...... | 9.228 | 2.520 | 23.04 | Turbid; strong odor.. ............ |
| " | 28 | 388.4 | 19.0 | 0.00 | 48.852 | ...... | 6.040 | 3.080 | 17.56 | Opalescent; strong odor ......... |
| Feb. | 4 | 419.0 | 41.0 | 0.00 | 52.000 | ...... | 5.300 | 1.960 | 19.68 | Opalescent; slight odor.......... |
| " | 11 | 360.0 | 15.2 | 0.00 | 40.710 | ...... | 6.512 | 1.960 | 21.76 | Nearly clear; marked odor....... |
| " | 18 | 292.0 | 13.1 | 0.00 | 43.542 | ...... | 9.120 | 2.010 | 20.48 | " " " ....... |
| " | 25 | 466.0 | 30.0 | 0.00 | 65.950 | ...... | 11.015 | 3.400 | 29.28 | Opalescent; strong odor. ........ |
| Mar. | 4 | 416.4 | 54.9 | 0.00 | 56.720 | ...... | 9.400 | 2.440 | 24.08 | Opalescent; slight odor.. ........ |
| Mean.. | | 408.6 | 21.6 | 0.00 | 56.083 | ...... | 8.149 | 2.489 | 22.82 | |

The mean values for the summer tests as compared with those obtained for Bridgeport show a moderate loss of organic matter but much less than in 1886. This can, doubtless, be explained in two ways. Because of the lower temperature the change was less rapid, and I believe it also true that at Bridgeport the water was not yet in a condition to yield its maximum of decomposition products. Consequently changes took place in the level between Bridgeport and Lockport, which in the former season took place in the Chicago river.

It will be observed that very much less sediment is found at Lockport than at Bridgeport during this period, and it may be urged that most of the improvement can be traced to this, but on several dates the sediment at Lockport was high while at the same time no corresponding increase of albuminoid ammonia or oxygen consumption is apparent.

The winter tests are instructive in this connection. The amount of suspended matter is small while a marked increase in albuminoid ammonia and oxygen consumption can be seen, as compared with the summer condition. Compared with Bridgeport the winter tests show but little improvement. Indeed, there is at times an apparent increase in organic matter.

The theory of retarded rate of oxidation by colder weather affords the best explanation of these peculiarities.

## JOLIET.

At Joliet two series of tests were made. The samples for the first test were taken at Lock 5, those for the second below dam No. 2. Some distance above the point where the first samples were taken the canal unites with the Desplaines river, but so little water came down the stream during most of the season that its diluting effect may be left out of consideration.

The analyses of the Joliet samples are given in tables IV. and V.

In the four miles between Lockport and dam No. 2, the reduction is quite apparent. It must also be remembered that the sewage of the state prison enters above this point, and practically in an unchanged condition as it flows through a closed sewer. The nature of this sewage is such as to largely increase, at times, the chlorides, as it contains salt and other chlorine compounds produced by processes in operation in the prison shops.

These compounds undoubtedly assist in retarding oxidation in the sewage which they accompany, so that it is discharged in a comparatively fresh condition into the canal.

A part of the drainage from Joliet itself enters the canal above the point where the samples were taken.

TABLE IV.—JOLIET (UPPER.)

| Date. 1888. | | Total solids... | Suspended matter..... | Nitrogen in Nitrates..... | Chlorine..... | Hardness $CaCo^3$..... | Free Ammonia | Alb. Ammonia | Oxygen consumed..... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|---|
| *May | 3 | 589.5 | 97.0 | 0.00 | 59.47 | 276.0 | 15.870 | 4.250 | 30.00 | Turbid; strong odor........... |
| " | 10 | 504.8 | 158.0 | 0.00 | 51.89 | 253.0 | 8.560 | 1.840 | 25.70 | Light turbidity; odor plain..... |
| " | 17 | 387.5 | 48.5 | 0.00 | 19.03 | 261.0 | 3.987 | 1.137 | 13.92 | Light brown; odor distinct...... |
| " | 24 | 422.2 | 66.9 | 0.00 | 36.86 | 258.0 | 3.470 | .940 | 14.24 | Light colored sediment; odor bad .......................... |
| " | 31 | 433.0 | 82.5 | 0.00 | 57.00 | 262.8 | 8.320 | .930 | 13.76 | Turbid............................ |
| June | 7 | 403.5 | 70.7 | 0.00 | 24.78 | 239.0 | 4.970 | .910 | 13.92 | Slightly turbid; yellowish; strong odor............................ |
| " | 14 | 374.0 | 86.8 | 0.00 | 28.32 | 216.0 | 6.400 | 1.790 | ...... | Slightly turbid; yellowish; strong odor............................ |
| " | 21 | 419.8 | 142.0 | 0.00 | 35.40 | 234.0 | 8.040 | 1.540 | 14.08 | Light colored sediment; strong odor............................ |
| Mean.. | | 441.7 | 94.0 | 0.00 | 39.09 | 249.9 | 7.452 | 1.667 | 15.70 | |

TABLE V.—JOLIET (DAM 2.)

| Date. 1888. | | Total Solids... | Suspended matter ...... | Nitrogen in Nitrates...... | Chlorine...... | Hardness $CaCo^3$... ... | Free Ammonia | Alb. Ammonia. | Oxygen consumed...... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|---|
| *May | 3 | 594.0 | 156.0 | 0.00 | 60.200 | 263.3 | 14.480 | 3.300 | 25.200 | Turbid; odor strong ............... |
| " | 10 | 559.5 | 121.0 | 0.00 | 48.140 | 252.0 | 7.900 | 2.000 | 23.040 | Light color'd sedim'nt; odor plain |
| " | 17 | 414.0 | 46.5 | 0.00 | 23.010 | 276.0 | 3.925 | .887 | 14.640 | " " " " " |
| " | 24 | 441.0 | 56.4 | 0.00 | 28.320 | 252.0 | 3.530 | .920 | 11.680 | Light; turbid; odor bad.......... |
| " | 31 | 447.4 | 84.5 | 0.00 | 55.990 | 280.0 | 8.300 | .985 | 12.520 | Turbid.............................. |
| June | 7 | 413.6 | 61.1 | 0.00 | 25.381 | 240.0 | 6.300 | .950 | 13.280 | Slightly turbid; yellowish; strong odor ................................ |
| " | 14 | 395.4 | 96.9 | 0.00 | 27.720 | 218.0 | 6.600 | 1.480 | 13.120 | Slightly turbid; yellowish; strong odor ................................ |
| " | 21 | 436.3 | 159.4 | 0.00 | 34.970 | 220.0 | 7.360 | 1.020 | 12.800 | Light sediment, stro g odor .... |
| " | 28 | 385.2 | 131.2 | 0.00 | 48.334 | 208.0 | 8.960 | 1.470 | 15.440 | Very turbid; odor strong ......... |
| July | 5 | 395.5 | 87.6 | 0.00 | 39.716 | 212.0 | 9.100 | 2.100 | 12.880 | Brownish; slightly turbid; odor perceptible......................... |
| " | 12 | 569.9 | 172.0 | 0.00 | 91.234 | 246.0 | 20.800 | 2.080 | 18.240 | Turbid; strong o.lor ............... |
| " | 19 | 456.4 | 103.7 | 0.00 | 58.056 | 246.0 | 12.720 | 1.540 | 14.000 | " " " ............... |
| " | 26 | 381.2 | 82.8 | 0.00 | 12.733 | 198.0 | 8.830 | 1.030 | 13.600 | " " " ............... |
| Aug. | 2 | 842.0 | 505.2 | 0.00 | 63.720 | 218.0 | 13.720 | 3.000 | 21.200 | Very turbid; bad odor............. |
| " | 9 | 404.2 | 85.0 | 0.00 | 46.253 | 226.0 | 6.240 | 1.860 | 9.760 | Light colored sediment; odor perceptible ........................... |
| " | 16 | 345.5 | 56.3 | 0.00 | 33.630 | 192.0 | 6.200 | .920 | 11.680 | Slight turbidity; odor plain...... |
| " | 23 | 331.5 | 126.5 | 0.00 | 36.816 | 168.0 | 5.740 | 1.520 | 13.596 | Light colored sediment; bad odor |
| " | 30 | 376.2 | 52.8 | 0.00 | 41.100 | 198.0 | 3.100 | 1.388 | 11.840 | Opalescent; strong oder.......... |
| Sept. | 6 | 353.0 | 43.5 | 0.00 | 38.940 | 176.0 | 10.820 | 2.060 | 13.920 | " " " .......... |
| " | 13 | 370.4 | 53.5 | 0.00 | 38.586 | 185.0 | 10.004 | 1.460 | 10.000 | " " " .......... |
| " | 15 | 382.0 | 56.9 | 0.00 | 51.684 | 179.0 | 7.360 | 1.900 | 6.840 | Slight turbidity; bad odor ....... |
| " | 20 | 562.0 | 96.0 | 0.00 | 35.400 | 220.0 | 14.280 | 2.080 | 11.520 | Dark sediment; bad ouor......... |
| " | 27 | 327.0 | 63.6 | 0.00 | 40.700 | 170.0 | 6.080 | 1.880 | 13.280 | Opalescent; strong odor.......... |
| Oct. | 5 | 374.4 | 84.1 | 0.00 | 36.728 | 180.0 | 10.010 | 2.660 | 17.440 | Slightly turbid; not much odor.. |
| " | 11 | 515.2 | 136.1 | 0.00 | 63.720 | 185.9 | 9.760 | 2.040 | 19.040 | Turbid................................ |
| " | 25 | 438.0 | 87.9 | 0.00 | 54.056 | 230.0 | 10.120 | 1.200 | 11.280 | " ................................ |
| Mean. | | 442.7 | 107.9 | 0.00 | 43.658 | 216.8 | 8.932 | 1.681 | 14.301 | |
| 1889. | | | | | | | | | | |
| Jan. | 14 | 436.2 | 37.0 | 0.00 | 60.181 | ...... | 7.840 | 2.680 | 24.600 | Opalescent; strong odor .......... |
| " | 21 | 516.0 | 100.0 | 0.00 | 53.454 | ...... | 7.980 | 2.480 | 19.440 | " " " .......... |
| " | 28 | 500.2 | 46.5 | 0.00 | 65.898 | ...... | 8.186 | 3.08 | 19.680 | " " " .......... |
| Feb. | 4 | 426.4 | 35.9 | 0.00 | 67.260 | ...... | 9.920 | 2.600 | 18.32 | " " " .......... |
| " | 11 | 397.0 | 36.8 | 0.00 | 60.180 | ...... | 9.900 | 2.28 | 23.20 | " " " .......... |
| " | 18 | 436.0 | 43.5 | 0.00 | 85.688 | ...... | 11.300 | 3.900 | 23.76 | " " " .......... |
| Mar. | 4 | 390.0 | 95.4 | 0.00 | 35.450 | ...... | 6.000 | 2.20 | 25.216 | Less odor than usual............. |
| " | 11 | 361.0 | 49.2 | 0.00 | 33.630 | ...... | 6.780 | 2.11 | 19.52 | " " " " ............. |
| Mean.. | | 432.8 | 55.5 | 0.00 | 57.717 | ...... | 8.488 | 2.666 | 21.717 | |

Comparing the summer and winter tests of the above tables it is apparent that the indications for organic matter are much stronger during the cold season.

* Table of mean temperature and precipitation at Joliet for May, June, July, August, September, October, A. D., 1888, with dates of days on which rain fell.—Miss Anna Nash, Observer.

| Months. | Temperature Deg. Fahr. | Rainfall—Inches. | Dates on which it rained. |
|---|---|---|---|
| May.................. | 56. | 8.50 | 3, 7, 8, 11, 16, 23, 24, 26, 27, 28, 30, 31......... |
| June................ | 68.7 | 1.70 | 17, 23, 28.................................. |
| July .................. | 72.4 | .70 | 8, 9.......................................... |
| August.............. | 65.5 | 6.00 | 1, 3, 15, 31................................. |
| September.......... | 58. | .90 | 16, 17......................................... |
| October ............ | 43.3 | 3.30 | 5, 15, 18..................................... |
| Total............ | ...................... | 21.10 | |

The difference in the determinations at Lockport, on May 3d and Joliet is owing to the fact that the samples at Lockport were collected in the morning, but those at Joliet in the afternoon; during this interval there was a very heavy rainfall.—J. H. R.

Unfortunately there are many irregularities in the summer analyses which render the drawing of satisfactory conclusions very difficult. Heavy rainfalls during May and June diluted the water so as to apparently decrease the chlorides, free and albuminoid ammonia. The addition of Joliet drainage and manufacturing waste likewise complicates our problem, because the amount so added is not well enough known to be brought into calculation.

The increase in suspended matter over the amount found at Lockport needs some explanation here. The samples reported in Table V, were taken below the dam, where a great deal of sediment was brought into circulation by the force of the falling water. Most of this matter is apparently of mineral origin and heavy, as it settles soon. The indications of the last column frequently contradict the numbers given in the record, as a light degree of turbidity may be occasioned by a comparatively heavy sediment, and *vice versa*. The waters called opalescent hold very finely divided matter in suspension.

Taking all these points into consideration, it is plain that during the summer there was a moderate degree of oxidation between Lockport and the Joliet dam, and that during the winter the improvement by oxidation was practically zero. In fact, the albuminoid ammonia tests show, apparently, an increase during the winter at the lower point. I shall refer to this below.

## THE ILLINOIS RIVER AND ITS TRIBUTARIES.

Between Joliet and Morris, where the first Illinois river sample was taken, the water of the canal mixes with that of the Kankakee and DuPage. Samples taken from the Kankakee at Wilmington, and from the DuPage, near Channahon, show the general character of these waters. Many of the samples received from Channahon were taken too near the m. uth of the river, and were contaminated with canal water. Those sent after August 3d were taken half a mile up stream, and show its true condition. The analyses are given in Table VI.

TABLE VI.—CHANNAHON (DuPage River.)

| Date. | | Total Solids... | Suspended matter...... | Nitrogen in Nitrates..... | Chlorine...... | Hardness $CaCO^3$...... | Free Ammonia | Alb. Ammonia. | Oxygen consumed...... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|---|
| May | 4 | 347.5 | 26.0 | .156 | 31.150 | 252.0 | 4.700 | .925 | 8.000 | Slightly colored; clear; odorless. |
| " | 11 | 353.0 | 24.0 | .882 | 8.250 | 249.0 | .689 | .395 | 7.440 | Nearly colorless; odorless........ |
| " | 18 | 322.9 | 16.0 | .315 | 11.920 | 250.2 | 1.271 | .394 | 7.600 | Colorless; slight earthy odor.... |
| " | 25 | 372.8 | 62.3 | .441 | 8.500 | 276.0 | .306 | .614 | 8.640 | Yellowish; earthy odor........... |
| June | 1 | 322.5 | 31.7 | 1.764 | 7.788 | 240.0 | .534 | .426 | 9.680 | Nearly clear; bad odor............ |
| " | 8 | 321.2 | 18.5 | .867 | 7.080 | 230.0 | .405 | .459 | 6.560 | Slightly turbid; yellowish; earthy odor............................ |
| " | 15 | 345.8 | 13.7 | .252 | 19.116 | 206.0 | 1.596 | .402 | 8.480 | Slightly turbid; yellowish; earthy odor............................ |
| " | 22 | 318.8 | 18.6 | t: ace | 34.196 | 226.0 | 4.230 | .600 | 6.480 | Nearly clear; yellowish; earthy odor............................ |
| " | 29 | 305.0 | 23.9 | .693 | 37.520 | 222.0 | 4.870 | .600 | 6.080 | Nearly clear; yellowish; earthy odor............................ |
| July | 6 | 418.4 | 11.7 | .315 | 56.640 | 216.0 | 9.580 | .605 | 5.160 | Nearly clear; yellowish; earthy odor............................ |
| " | 13 | 317.0 | 17.3 | 1.260 | 9.204 | 236.0 | .670 | .360 | 5.200 | Slightly opalescent; earthy odor |
| " | 20 | 354.9 | 11.0 | trace | 45.782 | 218.0 | 7.180 | .770 | 7.120 | Clear, yellow; odorless........... |
| " | 27 | 389.0 | 10.5 | .240 | 46.720 | 218.0 | 5.020 | .465 | 7.360 | Nearly clear; earthy odor........ |
| Aug. | 3 | 304.9 | 7.2 | trace | 45.428 | 184.0 | 7.520 | .540 | 4.900 | Opalescent yellow; earthy odor. |
| " | 10 | 306.5 | 13.5 | trace | 8.142 | 260.0 | .920 | .520 | 4.320 | Opalescent;colorless;earthy odor |
| " | 17 | 281.2 | 17.8 | .756 | 1.532 | 220.0 | .400 | .360 | 5.360 | Opalescent; yellow; earthy odor. |
| " | 24 | 250.1 | 14.1 | trace | 5.664 | 220.0 | .370 | .330 | 4.800 | " " " " |
| " | 31 | 284.1 | 11.6 | .200 | 6.726 | 250.0 | .780 | .420 | 5.120 | Slight opalescence; colorless; earthy odor...................... |
| Sept. | 7 | 308.0 | 12.2 | 1.197 | 5.426 | 254.0 | .142 | .234 | 5.200 | Slight opalescence; colorless; earthy odor...................... |
| " | 14 | 308.0 | 14.5 | trace | 6.761 | 240.0 | .134 | .290 | 4.400 | Slight opalescen.e; colorless; earthy odor...................... |
| " | 21 | 325.0 | 15.5 | ...... | 6.250 | 270.0 | .176 | .266 | 4.000 | Clear; odorless.................... |
| *Mean . | | 294.7 | 14.1 | .307 | 5.786 | 244.8 | .417 | .346 | 4.743 | |

* Mean for last 7.

TABLE VII.—WILMINGTON (Kankakee River.)*

| Date. | | Total Solids... | Suspended matter...... | Nitrogen in Nitrates...... | Chlorine...... | Hardness CaCO$^3$...... | Free Ammonia | Alb. Ammonia. | Oxygen consumed...... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|---|
| May | 4 | 230.3 | 11.0 | .060 | 1.180 | 165.6 | .125 | .660 | 11.600 | Greenish color; clear; odorless.. |
| " | 11 | 244.5 | 15.0 | .151 | 1.270 | 172.2 | .103 | .620 | 14.400 | Yellowish, clear; odorless........ |
| " | 18 | 269.0 | 16.0 | .060 | 1.530 | 213.6 | .076 | .590 | 14.880 | " " " |
| " | 25 | 246.6 | 12.2 | ...... | 1.160 | 196.8 | .044 | .460 | 13.049 | Slightly colored; earthy ordor ... |
| June | 1 | 422.2 | 274.0 | 1.323 | 1.180 | 141.6 | .100 | .784 | 19.520 | Muddy, odorless, nearly clear ... |
| " | 8 | 251.4 | 20.7 | ...... | 1.065 | 140.0 | .093 | .580 | 15.200 | Yellowish; earthy odor; nearly clr |
| " | 15 | 253.0 | 16.2 | trace | .708 | ...... | .077 | .710 | 12.320 | Yellowish, earthy odor, slightly turbid.............................. |
| " | 22 | 271.4 | 19.2 | ...... | 1.770 | 218.0 | .088 | .702 | 15.480 | Yellowish, odorless................ |
| July | 6 | 211.7 | 29.5 | trace | 1.062 | 146.0 | .090 | .448 | 11.120 | Opalescent, yellowish, earthy odor.................................. |
| " | 13 | 223.2 | 42.3 | .189 | 2.584 | 138.0 | .087 | .480 | 14.329 | Yellowish, o orless, nearly clear. |
| " | 27 | 212.5 | 13.4 | trace | .354 | 194.0 | .104 | .496 | 14.160 | Yellow, earthy odor............... |
| Aug. | 3 | 226.4 | 10.2 | ...... | .708 | 174.0 | .084 | .586 | 13.200 | Clear, yellow, earthy odor. ...... |
| " | 10 | 205.0 | 22.0 | ...... | 1.062 | 160.0 | .230 | .584 | 8.480 | Slight cloudiness, yellowish earthy odor...................... |
| " | 17 | 206.2 | 14.0 | ...... | .354 | 144.0 | .112 | .630 | 13.020 | Opalscent, yellow, odorless...... |
| " | 24 | 216.4 | 18.5 | ...... | .354 | 148.0 | .094 | .582 | 9.280 | Opalscent, yellow, slight earthy odor.................................. |
| " | 31 | 241.3 | 27.8 | ...... | .354 | 182.0 | .098 | .378 | 12.000 | Opalscent, yellow, slight earthy odor.................................. |
| Sept. | 7 | 269.2 | 32.4 | ...... | .944 | 188.0 | .086 | .730 | 10.120 | Opalscent, yellow, slight earthy odor.................................. |
| " | 14 | 304.0 | 47.7 | ...... | .460 | 190.0 | .214 | .600 | 10.400 | Opalescent, yellowish, odorless.. |
| " | 21 | 273.0 | 34.2 | ...... | 1.175 | 206.0 | .272 | .494 | 8.000 | " " " |
| Mean.. | | 251.4 | 35.6 | .094 | 1.015 | 164.1 | .114 | .585 | 12.661 | |

The flow during the latter part of the season was very small, however, and its effect in forming the character of the Illinois river must be considered as insignificant. With the Kankakee the case is different. The flow here is considerable, and the character of the water important. From Table VII. it will be seen that the amount of organic matter in this water, as indicated by albuminoid ammonia and oxygen consumption, is quite large, and although it is undoubtedly chiefly of vegetable origin, its effect must not be lost sight of. The Illinois water at Morris is practically made up of Kankakee river water and canal water, and it is important to know how one is modified by the other.

* Rainfall at Watseka, on one of the tributaries of the Kankakee, taken by Henry Upsall. May, 4.96; June, 4.43; July, 2.49; August, 0.61; September, 0.50; October, 3.36. Total, in inches, 16.35.—J. H. R.

**TABLE VIII.—MORRIS.**

| Date. 1888. | | Total Solids... | Suspended matter...... | Nitrogen in Nitrates ...... | Chlorine...... | Hardness $CaCO_3$...... | Free Ammonia | Alb. Ammonia. | Oxygen consumed...... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|---|
| May | 5 | 440.5 | 40.0 | .000 | 32.400 | 241.8 | 7.91 | .725 | 12.64 | Color dark; odor distinct......... |
| " | 12 | 407.0 | 28.5 | .000 | 21.240 | 241.2 | 3.54 | .706 | 12.00 | Yellowish; earthy odor........... |
| " | 19 | 386.7 | 18.5 | ...... | 21.830 | 255.6 | 1.924 | .761 | 13.52 | Slight color; earthy odor......... |
| " | 26 | 387.5 | 29.2 | ...... | 23.010 | 272.4 | .338 | .560 | 8.16 | Nearly clear; odor very slight .. |
| June | 2 | 303.0 | 53.0 | 2.457 | 3.540 | 213.6 | .100 | .530 | 10.96 | Muddy, earthy odor............... |
| " | 9 | 364.9 | 18.7 | ...... | 24.280 | 220.0 | 3.450 | .602 | 13.12 | Slightly turbid, yellow, earthy odor.............................. |
| " | 16 | 359.5 | 27.4 | 1.008 | 27.416 | 252.0 | 5.420 | .510 | 9.84 | Slightly turbid, yellow, earthy odor.............................. |
| " | 23 | 318.5 | 23.0 | trace | 25.346 | 226.0 | 3.305 | .545 | 12.08 | Nearly clear, yellowish, earthy odor.............................. |
| " | 30 | 287.9 | 49.7 | .250 | 7.682 | 222.0 | .995 | .642 | 13.92 | Nearly clear, yellowish, earthy odor.............................. |
| July | 7 | 287.7 | 18.5 | trace | 12.956 | 174.0 | 3.036 | .554 | 11.60 | Opalescent, yellowish, some odor. |
| " | 14 | 313.0 | 38.7 | trace | 16.496 | 188.0 | 2.750 | .665 | 13.12 | Opalescent, earthy odor.......... |
| " | 21 | 340.1 | 36.5 | .504 | 31.622 | 202.0 | 4.150 | .600 | 16.960 | Nearly clear, yellow, ordorless.. |
| " | 28 | 441.6 | 120.0 | .378 | 14.200 | 206.0 | 3.910 | .886 | 13.840 | Very turbid, earthy odor......... |
| Aug. | 4 | 330.5 | 24.5 | .180 | 39.407 | 190.0 | 4.00 | .540 | 9.120 | Opalescent, yellow, earthy odor. |
| Sept. | 1 | 376.0 | 32.5 | ...... | 33.984 | 210.0 | 4.890 | 1.090 | 7.680 | Colorless, odorless, light floating matter........................ |
| " | 8 | 433.0 | 17.8 | 4.032 | 49.206 | 250.0 | 8.040 | .570 | 8.000 | Clear, yellow, earthy odor ....... |
| " | 15 | 372.4 | 9.0 | ...... | 48.852 | 188.0 | 6.240 | .800 | 6.320 | Clear, earthy odor ................ |
| " | 17 | 282.0 | 3.9 | trace | 34.691 | 180.0 | 3.820 | 1.050 | 6.240 | " " " |
| " | 22 | 370.0 | 6.4 | ...... | 47.082 | 192.0 | 5.800 | 1.080 | 7.200 | Clear and odorless................ |
| " | 29 | 343.0 | 11.5 | trace | 56.640 | 222.0 | .928 | .670 | 7.520 | Clear, colorless, slight odor...... |
| Oct. | 6 | 273.4 | 6.5 | trace | 38.740 | 182.0 | 6.820 | .630 | 5.600 | " " " " |
| " | 13 | 360.0 | 22.5 | ...... | 56.990 | 210.0 | 12.62 | .950 | 11.760 | Clear, slightly yellowish, strong odor.............................. |
| " | 20 | 355.8 | 60.3 | ...... | 54.600 | 204.0 | .841 | .088 | 8.480 | Yellow, odorless.................. |
| " | 27 | 408.6 | 43.8 | ...... | 44.375 | 210.0 | 3.460 | 1.200 | 22.400 | Very dirty, strong odor.......... |
| Mean.... | | 355.9 | 30.85 | .367 | 32.149 | 214.8 | 4.107 | .707 | 10.920 | |
| 1889 | | | | | | | | | | |
| Jan. | 14 | 349.5 | 13.0 | 0.00 | 28.320 | ...... | 4.560 | 1.360 | 9.100 | Nearly clear; earthy odor........ |
| " | 21 | 346.6 | 13.5 | 0.00 | 21.948 | ...... | 4.040 | 1.020 | 7.920 | Nearly clear; odorless............ |
| " | 28 | 416.0 | 13.9 | 0.00 | 23.010 | ...... | 5.680 | 1.460 | 8.320 | Nearly clear; organic odor. ...... |
| Feb. | 4 | 381.0 | 33.0 | 0.00 | 31.650 | ...... | 5.300 | 1.800 | 9.100 | Nearly clear; earthy odor........ |
| " | 11 | 390.0 | 29.3 | 0.00 | 33.630 | ...... | 5.710 | 2.700 | 10.50 | " " " " ...... |
| " | 18 | 280.0 | 32.5 | 0.00 | 14.160 | ...... | 2.640 | 1.200 | 8.210 | Opalescent; slight odor .......... |
| " | 25 | 463.0 | 69.2 | 0.00 | 40.456 | ...... | 7.920 | 1.520 | 14.22 | Turbid; strong odor.............. |
| Mar. | 4 | 276.0 | 28.2 | 0.00 | 36.816 | ...... | 1.880 | 1.640 | 18.20 | Opalescent; yellowish; strong odor .............................. |
| Mean.. | | 325.2 | 29.1 | 0.00 | 28.748 | ...... | 4.716 | 1.587 | 10.696 | |

Table VIII. gives the results found by analyses of the Morris samples. Comparing the winter with the summer results the increased albuminoid ammonia of the colder weather is very apparent. There is no increase in suspended matter and probably no important change in concentration as the chlorine remains about the same.

During the summer months the decrease in albuminoid ammonia and oxygen consumption between Joliet and Morris indictaes an important loss of organic matter. It might appear that this is largely due to sedimentation, as the difference in suspended matter between Joliet and Morris is likewise large. But the high suspended matter at Joliet is largely made up of fine mineral particles, as the water at that point was taken immediately below the dam, where the agitation was great.

The dilution by Kankakee water can not explain much of this reduction because of its own large amount of nitrogenous organic matter. The proportion of Kankakee water at Morris can be approximately estimated by considering that the decrease in chlorides is due to dilution with a water containing much less chlorine. Knowing the amount of chlorine at the three points, Joliet, Wilmington and Morris, and assuming that there is no loss in chlorine on the way, which is practically true, a little calculation will give us the amount of Kankakee water mixed with that from Joliet to furnish the observed average at Morris. In this way I find the dilution to be about 20 per cent.

Supposing now no change to take place in the nitrogenous constituents the mixture of Kankakee and canal water should give a product yielding 1.46 per million of albuminoid ammonia, but we have an average of less than half of that, for the summer.

The oxygen consumption sinks at Morris below that found for the Kankakee, which is another strong evidence of purification.

Probably fifty per cent. of the organic matter present at Joliet is decomposed before Morris is reached. After leaving Morris the river flows without dilution to Ottawa, where the Fox enters. Table IX gives analyses of the water of this stream.

The next regular samples were taken at LaSalle and below the entrance of the Big and Little Vermilion rivers. The flow from both of those streams was comparatively small during most of the time of the examinations.

Tables X, XI and XII contain the results of the analyses of these two waters and of the Illinois.

TABLE IX.—OTTAWA (Fox River.)

| Date. 1888. | | Total Solids... | Suspended matter...... | Nitrogen in Nitrates ...... | Chlorine...... | Hardness $CaCO^3$...... | Free Ammonia | Alb. Ammonia. | Oxygen consumed...... | Physical Conditions. | ‡Mean temperature week ending...... | ‡Total rainfall week ending |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| May | 14 | 281.0 | 5.0 | ...... | 3.19 | 244.2 | .079 | .365 | 9.76 | Nearly clear; slight earthy odor........... | 50.51 | .81 |
| " | 21 | 281.8 | 13.6 | .126 | 2.94 | 220.8 | .116 | .450 | 6.64 | Nearly clear; Slight earthy odor .......... | 50.47 | .48 |
| " | 28 | 280.9 | 28.3 | trace | 1.77 | 222.6 | .084 | .360 | 6.60 | Turbid from rain; earthy odor .......... | 64.20 | 2.33 |
| June | 5 | 322.5 | 50.6 | ...... | 2.90 | 248.4 | .088 | .394 | 8.60 | Clear; slight color; odorless.............. | 58.58 | .38 |
| " | 11 | 312.5 | 18.6 | ...... | 3.540 | 250.0 | .068 | .344 | 6.72 | Slightly turbid; yellowish; odorless.......... | 64.02 | .00 |
| " | 18 | 333.8 | 30.1 | ...... | 4.650 | 288.0 | .128 | .452 | 5.28 | Nearly clear; yellowish; odorless.......... | 75.61 | .47 |
| " | 25 | 368.0 | 51.0 | .060 | 4.720 | 280.0 | .122 | .490 | 7.60 | Nearly clear; yellowish; odorless. ........ | 75.41 | .25 |
| July | 2 | 285.2 | 20.3 | ...... | 2.94 | 252.0 | .086 | .296 | 5.60 | Nearly clear; yellowish; odorless ......... | 66.91 | .36 |
| " | 9 | 620.2 | 400.4 | .125 | 7.496 | 146.0 | .272 | 1.140 | 9.28 | Muddy...... ........... | 74.72 | 1.54 |
| " | 16 | 320.5 | 43.1 | trace | 5.897 | 253.0 | .140 | .308 | 6.08 | Opalescent; odorless.. | 69.36 | .00 |
| " | 23 | 314.0 | 30.3 | trace | 7.434 | 254.0 | .100 | .358 | 4.72 | " " .. | 71.45 | .20 |
| *Aug. | 6 | 463.2 | 41.8 | .180 | ........ | ...... | 3.118 | .602 | 13.760 | Nearly clear; yellow; earthy odor............ | 75.31 | 1.11 |
| " | 13 | 335.0 | 24.6 | ...... | 8.021 | 236.0 | .084 | .336 | 6.000 | Opalescent; yellowish; odorless................ | 61.24 | .22 |
| " | 20 | 279.2 | 22.0 | trace | 4.248 | 244.0 | .226 | .910 | 6.640 | Opalescent; yellowish; earthy odor ........... | 71.75 | 1.72 |
| " | 27 | 287.8 | 8.8 | ...... | 4.176 | 240. | .066 | .278 | 5.120 | Nearly clear; slight earthy odor........... | 66.67 | .00 |
| Sept. | 3 | 284.2 | 8.0 | ...... | 7.667 | 250. | .054 | .420 | 7.520 | Nearly clear; slight earthy odor .......... | 65.45 | .01 |
| " | 10 | 290.5 | 25.4 | ...... | 5.189 | 248. | .088 | .440 | 6.400 | Floating matter; yellowish; earthy odor . | 62.69 | .29 |
| " | 17 | 286.0 | 12.5 | ...... | 7.788 | 240. | .095 | .400 | 4.880 | Clear; odorless ........ | 57.37 | 1.07 |
| Mean . | | 330.3 | 46.3 | .027 | 4.974 | 242.1 | .278 | .463 | 7.066 | | | |

* Not enough water sent.

‡ These observations are the means of the records from Aurora and Oswego—the nearest available places. Dr. M. M. Robbins, Observer, Aurora; John Seely, Observer, Oswego.—J. H. R.

TABLE X.—LASALLE (Big Vermilion.)

| Date. 1888. | | Total Solids... | Suspended matter... | Nitrogen in Nitrates... | Chlorine... | Hardness $CaCO_3$... | Free Ammonia | Alb. Ammonia | Oxygen consumed... | Physical Conditions. | *Mean temperature week ending... | *Total rainfall week ending. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| May | 7 | 618.0 | 258.5 | 1.323 | 6.48 | 242.4 | .180 | .693 | 9.04 | Turbid; no odor; yellowish. | 41.76 | 1.46 |
| " | 14 | 457.5 | 101.0 | 2.140 | 2.58 | 213.6 | .142 | .270 | 8.40 | Slight earthy odor; yellowish | 39.11 | .2 |
| " | 21 | 378.5 | 25.3 | 4.347 | 4.70 | 244.8 | .002 | .194 | 3.36 | Slightly turbid; odorless | ...... | 1.00 |
| " | 28 | 456.9 | 101.5 | 4.914 | 4.106 | 260. | .073 | .340 | 6.64 | Nearly clear; odorless. | ...... | 3.02 |
| June | 11 | 429.5 | 22.3 | 3.970 | 6.440 | 290. | .015 | .182 | 7.20 | Colorless; odorless; floating organic matter | 53.89 | .00 |
| " | 18 | 436.2 | 60.0 | 2.898 | 9.204 | 278. | .418 | .440 | 5.60 | Nearly clear; yellowish; odorless | 63.40 | 1.58 |
| July | 16 | 377.5 | 46.2 | 3.843 | 4.718 | 262. | .077 | .270 | 8.160 | Opalescent; earthy odor | 61.14 | .15 |
| Mean. | | 450.6 | 87.8 | 3.348 | 5.461 | 255.8 | .129 | .341 | 6.914 | | | |

TABLE XI.—LASALLE (Little Vermilion.)

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| May | 7 | 446.0 | 37.5 | .207 | 6.44 | 112.8 | .348 | .358 | 5.44 | Light yellow; earthy color; floating organic matter | ...... | .... |
| " | 14 | 346.0 | 10.0 | .252 | 4.71 | 177.0 | .079 | .250 | 5.08 | Odorless; colorless | ...... | .... |
| " | 21 | 420.3 | 48.4 | .125 | 4.25 | 132. | .038 | .436 | 4.96 | Light brown; earthy odor | ...... | .... |
| " | 28 | 468.5 | 44.5 | 1.700 | 4.460 | 308. | .062 | .278 | 10.40 | Nearly clear; colorless; odorless | ...... | .... |
| June | 11 | 314.7 | 13.7 | .126 | 6.478 | 238. | .342 | .434 | 7.60 | Colorless; floating organic matter | ...... | .... |
| " | 18 | 325.0 | 25.3 | ...... | 5.876 | 250. | .082 | .674 | 7.76 | Nearly clear; yellowish; odorless | ...... | .... |
| July | 16 | 305.5 | 36.2 | .125 | 7.434 | 254. | .312 | .450 | 8.80 | Slightly turbid; yellow; earthy odor | ...... | .... |
| Mean. | | 375.1 | 30.8 | .362 | 5.664 | 210.2 | .180 | .411 | 7.15 | | | |

TABLE XII.—LASALLE (Illinois River.)

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| May | 7 | 327.5 | 26.2 | .228 | 13.31 | 192.0 | .638 | .500 | 11.36 | Yellowish; odorless | †52.14 | †.55 |
| " | 14 | 395.5 | 45.3 | 1.070 | 13.81 | 219.0 | 1.080 | .608 | 11.04 | Brownish; " | 53.32 | 1.03 |
| " | 21 | 314.9 | 11.5 | .630 | 8.85 | 228.0 | .216 | .402 | 4.40 | Yellowish; earthy odor | 52.57 | .56 |
| " | 28 | 318.5 | 43.0 | 1.638 | 5.664 | 204.0 | .076 | .492 | 12.64 | Nearly clear; odorless. | 64.89 | 3.25 |
| June | 11 | 318.9 | 15.5 | 1.320 | 9.204 | 240.0 | .176 | .480 | 11.36 | " " " | 65.43 | .10 |
| " | 18 | 333.0 | 34.2 | .630 | 12.954 | 242.0 | .201 | .546 | 10.64 | " " " | 73.94 | .94 |
| " | 25 | 327.9 | 55.5 | .567 | 10.620 | 256.0 | .118 | .446 | 10.00 | Slightly turbid; yellowish; odorless | 73.78 | .77 |
| July | 2 | 527.7 | 326.5 | .504 | 3.640 | 112.0 | .104 | .540 | 6.00 | Very t'rbid; earthy odor | 67.40 | .07 |
| " | 9 | 364.0 | 152.2 | .880 | 7.650 | 136.0 | .238 | .700 | 9.840 | Turbid; yellowish; odorless | 73.70 | 2.54 |
| " | 16 | 301.7 | 68.3 | .900 | 9.583 | 166.0 | .049 | .490 | 12.04 | Turbid; earthy odor | 69.00 | .06 |
| " | 23 | 293.3 | 19.8 | .124 | 11.915 | 160.0 | .086 | .562 | 9.760 | Yellowish; nearly clear; earthy odor | 71.33 | .00 |
| " | 30 | 291.0 | 25.5 | .819 | 13.685 | 186.0 | .144 | .406 | 10.080 | Yellow; earthy odor; slightly turbid | 74.60 | .98 |
| Aug. | 6 | 291.0 | 29.4 | .315 | 24.780 | 190.0 | 1.014 | .550 | 9.280 | Opalescent; yellowish; earthy odor | 75.10 | .71 |
| " | 29 | 325.2 | 57.9 | 1.386 | 18.471 | 200. | .072 | .474 | 9.200 | Nearly clear; earthy odor | 66.42 | .00 |
| Sept. | 3 | 307.9 | 26.4 | .550 | 21.240 | 220. | .100 | .848 | 8.400 | Nearly clear; earthy odor; yellowish | 62.80 | .00 |
| " | 17 | 363.0 | 33.0 | 3.276 | 26.550 | 225. | .128 | .560 | 5.440 | Slightly turbid; earthy odor | 56.68 | .19 |
| " | 20 | 327.2 | 20.8 | 2.646 | 32.684 | 228. | .474 | .464 | 9.360 | Yellowish; nearly clear; earthy odor | ...... | .... |
| " | 24 | 351.4 | 25.2 | 1.890 | 27.728 | 239. | .125 | .540 | 5.040 | Nearly clear; earthy odor | 57.68 | .10 |

*These observations are furnished by Mr. Isaac Young, Observer, Pontiac—the nearest available point.—J. H. R.

†These data furnish d by Dr. J. O. Harris, Observer, Ottawa.

TABLE XII.—*Continued.*

| Date. 1888. | Total Solids... | Suspended matter...... | Nitrogen in Nitrates...... | Chlorine ...... | Hardness $CaCO^3$....... | Free Ammonia | Alb. Ammonia. | Oxygen consumed....... | Physical Conditions. | Mean temperature — week ending...... | Tot'l rainfall week ending. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Oct. 1 | 380.0 | 29.8 | 1.764 | 44.604 | 256. | 4.320 | .930 | 7.120 | Nearly clear; odorless; slightly yellow........ | 51.60 | .00 |
| " 8 | 377.0 | 18.0 | .760 | 39.294 | 240. | 1.584 | .450 | 6.720 | Opalescent; odorless.. | 44.78 | .53 |
| " 15 | 370.0 | 45.9 | 1.960 | 28.670 | 230. | .892 | .474 | 6.40 | Nearly clear; earthy odor................. | 47.21 | .09 |
| " 22 | 349.4 | 10.4 | trace | 35.672 | 260. | 1.336 | .340 | 4.80 | Nearly clear; odorless. | 41.18 | 1.67 |
| " 29 | 395.8 | 35.9 | ...... | 32.922 | 250. | 1.156 | .312 | 5.92 | " " " | 45.92 | .42 |
| Mean . | 345.7 | 50.3 | 1.037 | 19.717 | 211.7 | .623 | .526 | 8.558 | | | |
| 1889. | | | | | | | | | | | |
| Jan. 14 | 349. | 14. | 1.660 | 14.974 | ...... | 1.187 | .485 | 5.360 | Nearly clear; odorless. | 25.64 | 1.30 |
| " 21 | 310. | 21. | trace | 14.500 | ...... | .535 | .430 | 5.120 | Ne'rly clear; slight odor | 23.50 | .61 |
| " 28 | 449.4 | 92. | 2.709 | 11.428 | ...... | .926 | .372 | 5.360 | Turbid; earthy odor .. | 27.03 | .00 |
| Feb. 4 | 350. | 30. | 1.638 | 9.676 | ...... | 1.600 | .452 | ...... | Nearly clear; odorless. | 27.21 | .00 |
| " 11 | 338. | 4.2 | trace | 18.054 | ...... | 1.815 | .560 | 7.500 | Clear earthy odor; slightly turbid........ | 19.00 | .11 |
| " 18 | 379. | 61.5 | " | 20.296 | ...... | 2.456 | .821 | 9.800 | Yellow; earthy odor... | 21.64 | .87 |
| " 25 | 357. | 9.0 | 1.270 | 15.300 | ...... | 2.808 | .675 | 8.500 | Clear; odorless......... | 7.50 | .00 |
| Mar. 4 | 758. | 534.2 | 0.000 | 7.70 | ...... | .712 | 1.420 | 24.000 | Muddy; odorless....... | 32.25 | .65 |
| " 11 | 468. | 78.5 | 1.200 | 6.018 | ...... | 1.077 | .520 | 11.600 | Turbid; earthy odor... | 33.85 | .07 |
| Mean.. | 417.6 | 93.8 | .942 | 13.105 | ...... | 1.456 | .637 | 8.582 | | | |

It will be noticed that the results given in the above tables are very irregular. This is especially true of the data for the Big Vermilion river, and the Illinois during the early part of the season. It must be remembered that the rainfall at that time was heavy, producing abnormal conditions.

Comparing the winter and summer results as obtained at LaSalle, it would appear at first sight that the colder season shows a decrease instead of an increase of organic contamination, as indicated by albuminoid ammonia.

However, if we notice the chlorine found during the two periods, it is apparent that the dilution between Morris and LaSalle is far greater during the winter than during the summer. If we leave out of consideration the earlier summer tests and late winter tests, when the stream was abnormally diluted by heavy rains and melting snow, we find that the chlorine amounts to nearly twice as much during the summer as during the winter, which points to a correspondingly lower dilution by the Fox, Big Vermilion and Little Vermilion.

It is evident that the actual winter change has been less than the summer change here, as at Morris.

To estimate the amount of oxidation between Morris and LaSalle is not an easy matter. Considering especially the summer work, we notice with an increase of sediment a very decided reduction in the amount of free ammonia, but the changes as shown by the albuminoid ammonia and oxygen consumption are not as readily seen. The chlorine between Morris and LaSalle is reduced from 32 parts per 1,000,000 to about 20 parts, and by means of water containing about 6 parts per 1,000,000. This indicates a considerable dilution, but it must be remembered that the diluting water gives nearly as strong tests for organic matter as does the main stream. This organic matter

is mostly of vegetable origin and undoubtedly of a more stable type than that of sewage origin. The Kankakee adds about as much per 1,000,000 to the Illinois above Morris as there is present at LaSalle, and after the addition of fresh matter by the Fox and in some degree by the sewage of Ottawa, and finally by the Big and Little Vermilion rivers it is plain that we have no means of showing how much impurity indicated by the tests at LaSalle left the pumps at Bridgeport and how much was added by the tributaries.

The appearance of nitrates and nitrites in these waters is worthy of notice. The canal water at Bridgeport and Joliet seems to show only occasional traces of these products of oxidation, but at Morris they appear more regularly and are uniformly found below in the main stream. In most of the tributaries they are less abundant being practically absent from the Kankakee and Fox. The Big Vermilion, however, receiving a part of the drainage of Streator, contains more than the usual proportion.

It seems reasonably well established that these compounds, which are products of bacterial fermentation of ammoniacal salts are practically never found in fresh sewage. A certain time is required for their development and also the presence of an abundance of free oxygen. It is also reasonably well established that other easily fermentable bodies must not be present, as in such cases denitrification takes place with destruction of nitrates and evolution of free nitrogen even. Supposing a certain amount of nitrification to have taken place between Bridgeport and Lockport, it follows from numerous experiments that the oxygen of the nitrates so formed must be immediately given up to aid in other more fundamental processes, and consequently while free ammonia disappears the tests reveal no nitrates or nitrites. Observations bearing on similar phenomena have been made by Munro, Warington, Leone and others within the past few years.

In the Illinois river the bodies which lead to the destruction of nitrates or prevent their formation seem to disappear between Joliet and Morris, and it is interesting to note that the uniform appearance of nitrates is coincident with the slower disappearance of albuminoid ammonia in the river below Morris.

I believe this formation of nitrates can be taken as the indication of the completion of one of the important stages in the destruction of animal organic matters in water, that is, where the original contaminating substances have been broken up by ferment action, and derived products of less complexity but greater stability have taken their place. These products may be similar to leucine and tyrosine or other nitrogenous body referred to some distance back. The bacteria of denitrification can no longer live in such water.

Between LaSalle and Henry we have a stretch of 28 miles without dilution, except by rain. During the summer the consumption of oxygen is rather greater at the second place than at the first, but there is a decided reduction in free and albuminoid ammonia. It appears probable, therefore, that some destruction of organic matter goes on in this portion of the river.

The analyses are given in table XIII. The increased chlorides and free ammonia on Oct. 9th and 12th at Henry and on Oct. 1st and 8th at LaSalle are undoubtedly due to the diminished flow but stronger concentration of canal water pumped from Sept. 13th to 19th, when only half the pumps were in operation.

**TABLE XIII.—HENRY (Illinois River).**

| Date. 1888. | | Total Solids... | Suspended matter....... | Nitrogen in Nitrates...... | Chlorine....... | Hardness $CaCO_3$....... | Free Ammonia | Alb. Ammonia. | Oxygen consumed....... | Physical Conditions. | *Mean temperature week ending....... | *Total rainfall week ending. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| May | 10 | 285.5 | 13.0 | .258 | 12.49 | 208.8 | .568 | .470 | 10.40 | Yellowish; odorless ... | 56.2 | 1.44 |
| " | 17 | 307.1 | 11.0 | .472 | 11.32 | 234.0 | .727 | .510 | 9.60 | Yellow; earthy odor ... | ...... | .30 |
| " | 24 | 299.7 | 23.9 | .346 | 7.08 | 250.0 | .146 | .372 | 9.44 | " " " ... | ...... | .73 |
| June | 1 | 245. | 16.7 | .504 | 3.540 | 176.4 | .204 | .478 | 8.640 | Nearly clear; odorless. | 68.9 | 3.80 |
| " | 7 | 257. | 10.8 | 1.260 | 4.708 | 154.0 | .025 | .349 | 10.00 | " " " | ...... | .00 |
| " | 14 | 264.1 | 19.5 | ...... | 4.268 | 152.0 | .418 | .766 | 10.16 | Earthy odor; yellowish; nearly clear .......... | ...... | .... |
| July | 12 | 402.2 | 138.2 | .250 | 5.876 | 152. | .190 | .566 | 12.340 | Very t'rbid; earthy odor | 74.7 | .55 |
| " | 19 | 277.0 | 30.4 | 1.260 | 7.788 | 166. | .117 | .450 | 11.760 | Cloudy; earthy odor... | ...... | .00 |
| " | 26 | 267.5 | 24.8 | .420 | 30.677 | 186. | .196 | .43 | 13.040 | Slightly turbid; yellowish; earthy odor....... | ...... | .30 |
| Aug. | 4 | 332.0 | 32.0 | .660 | 11.788 | 186. | .182 | .514 | 9.600 | Opalescent; yellowish; odor earthy .......... | 71.0 | 2.15 |
| " | 9 | 282.0 | 20.2 | 1.134 | 15.346 | 200. | .360 | .550 | 7.360 | Opalescent; yellowish; odorless... .......... | ...... | .20 |
| " | 28 | 258.9 | 20.6 | 1.135 | 16.860 | 190. | .212 | .474 | 8.320 | Opalescent; yellowish; odorless ............... | ...... | .25 |
| Sept. | 14 | 326.8 | 24.5 | 1.008 | 21.240 | 198. | .332 | .526 | 6.800 | Nealy clear; odorless.. | 60.3 | .70 |
| " | 21 | 323.8 | 23.3 | 1.250 | 17.445 | 222. | .368 | .440 | 6.320 | " " " | ...... | .50 |
| " | 27 | 326.4 | 30.2 | 1.260 | 28.143 | 218. | .336 | .476 | 6.320 | " " " | ...... | .01 |
| Oct. | 9 | 355.4 | 15.0 | trace | 28.702 | 264. | 1.606 | .860 | 7.680 | Slightly opalescent; odorless............... | 47.3 | .30 |
| " | 12 | 355.4 | 39.0 | 1.764 | 38.230 | 228.0 | 1.526 | .428 | 5.680 | Nearly clear; odorless. | ...... | .00 |
| " | 22 | 314.4 | 15.7 | trace | 28.392 | 264.0 | .416 | .204 | 5.280 | " " " | ...... | 1.91 |
| " | 29 | 333.8 | 14.0 | " | 31.860 | 235.0 | .952 | .280 | 5.760 | " " " | ...... | .50 |
| Mean.. | | 306. | 27.5 | .683 | 17.660 | 204.4 | .467 | .481 | 8.657 | | | |
| 1889. | | | | | | | | | | | | |
| Jan. | 14 | 325. | 14. | trace | 12.390 | ...... | .985 | .300 | 6.300 | Clear; odorless ........ | ...... | 1.01 |
| " | 21 | 303. | 19.5 | 1.670 | 10.976 | ...... | 1.356 | .321 | 5.840 | " " ........ | ...... | .54 |
| " | 28 | 336. | 20.0 | 1.250 | 8.496 | ...... | .707 | .254 | 5.840 | " " ........ | ...... | .00 |
| Feb. | 25 | 264. | 9.5 | 1.890 | 18.808 | ...... | 1.320 | .714 | 12.40 | " earthy odor .... | ...... | .00 |
| Mar. | 4 | 354. | 91.5 | trace | 7.788 | ...... | .926 | .430 | 12.80 | Turbid; slight odor .... | ...... | .10 |
| Mean . | | 316. | 30.9 | .962 | 11.691 | ...... | 1.059 | .404 | 8.636 | | | |

Comparing the winter and summer tests we have in the colder season a decrease in suspended matter, decrease in chlorides, marked increase in free ammonia, and apparent decrease in albuminoid ammonia. Taking into consideration the greater dilution as indicated by the lower chlorides, it is probable that the albuminoid ammonia here is greater in winter than in summer, in proportion to the amount of Bridgeport water present.

Two sets of determinations were made at Peoria, 35 miles below Henry. In one case the water was taken from a hydrant in the city and in the other from the river—Lake Peoria—near the end of the inlet pipe. A single analysis was made of water taken at the "Narrows," some distance above. During the winter the samples were taken at the upper bridge, about a mile and a half above the inlet, and at a point removed from danger of local contamination.

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* Data furnished by A. T. Purviance, Observer, Hennepin.—J. H. R.

TABLE XIV.—PEORIA (Inlet.)

| Date. 1888. | Total Solids... | Suspended matter....... | Nitrogen in Nit ates...... | Chlorine....... | Hardness CaCO$^3$....... | Free Ammonia | Alb. Ammonia. | Oxygen consumed....... | Physical Condit ons. | *Mean temperature week ending...... | *Total rainfall week ending. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| May 9 | 277.0 | 14.5 | .220 | 9.910 | 189.5 | .172 | .625 | 17.100 | Yellowish; odorless.... | 60.28 | 1.69 |
| " 14 | 434.5 | 38.5 | .063 | 15.220 | 212.4 | .168 | .595 | 9.560 | Nearly clear; odorless. | 57.20 | .05 |
| " 21 | 316.4 | 7.7 | .535 | 10.370 | 215.0 | .436 | .372 | 8.240 | " " " | 59.75 | .36 |
| " 28 | 297.5 | 24.0 | .693 | 7.667 | 204.4 | .068 | .412 | 6.920 | Turbid; odorless. ...... | 70.47 | 4.49 |
| June 4 | 263.4 | 15.7 | .625 | 5.664 | 180.0 | .199 | .423 | 9.600 | Nearly clear; earthy odor.................. | 64.97 | .14 |
| " 11 | 1000.0 | 641.9 | 1.764 | 10.835 | 185.0 | .162 | .596 | 14.400 | Very turbid; strong earthy odor........... | 74.80 | .08 |
| " 25 | 282.9 | 11.8 | .252 | 8.258 | 240.0 | .220 | .480 | 9.520 | Clear; yellowish; odorless.................... | 77.66 | .68 |
| July 2 | 279.5 | 21.3 | .378 | 8.021 | 208.0 | .328 | .816 | 10.800 | Clear; yellowish; odorless.................... | 75.67 | .67 |
| " 9 | 295.9 | 76.4 | .221 | 19.470 | 186.0 | .148 | .446 | 8.720 | Slightly turbid; earthy odor.................. | 81.38 | 4.70 |
| " 16 | 210.5 | 11.2 | 2.830 | 5.543 | 154.0 | .056 | .468 | 9.760 | Slightly yellow; nearly clear; earthy odor. | 75.21 | .45 |
| " 23 | 289.0 | 10.6 | .260 | 7.080 | 190.0 | .087 | .562 | 9.120 | Clear; yellowish; slight earthy odor........... | 77.13 | .09 |
| " 27 | 309.5 | 46.5 | .360 | 7.450 | 182.0 | .234 | .500 | 10.240 | Opalescent; odorless .. | 81.07 | 1.24 |
| " 31 | 265.5 | 17.5 | .210 | 8.637 | 182.0 | .468 | .846 | 13.280 | Nearly clear; yellowish; odorless. ........ | 85.07 | .00 |
| Aug. 7 | 244.3 | 8.8 | .220 | 11.444 | 196.0 | .113 | .422 | 8.960 | Clear; yellow; earthy odor.................. | 81.03 | .35 |
| " 13 | 298.5 | 11.2 | 1.008 | 13.568 | 216.0 | .140 | .620 | 11.600 | Clear; yellow; earthy odor. ................ | 58.60 | .60 |
| Sept 17 | 284.2 | 14.8 | 2.520 | 17.700 | 186.0 | .224 | .480 | 8.000 | Nearly clear; odorless. | 60.83 | 1.07 |
| " 24 | 299.6 | 23.7 | 1.260 | 19.470 | 216.0 | .210 | .504 | 7.200 | " " " | 64.11 | 3.63 |
| Oct. 1 | 320.0 | 19.2 | 3.520 | 24.072 | 230.0 | .287 | .426 | 6.880 | " " " | 54.11 | .00 |
| " 8 | 297.2 | 16.0 | Tr'ce | 24.426 | 222.0 | .284 | .332 | 5.720 | " " " | 52.03 | .38 |
| Mean.. | 329.75 | 54.27 | .8915 | 12.358 | 199.7 | .210 | .522 | 9.769 | | | |

FROM THE NARROWS.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Aug. 10 | 276.4 | 16.6 | .230 | 12.390 | 200. | .166 | .408 | 8.480 | Opalescent; yellowish; odorless......... | 73.25 | .53 |

UPPER BRIDGE.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1889. Feb. 14 | 331.0 | 4.0 | 1.885 | 14.511 | ...... | 1.157 | .510 | 7.20 | Clear; odorless ........ | 28.35 | .13 |
| " 21 | 344.0 | 5.5 | 1.175 | 14.868 | ...... | 1.398 | .465 | 7.20 | Clear; earthy odor..... | 26.34 | .43 |
| " 25 | 346.0 | 11.6 | trace | 14.920 | ...... | 2.444 | .645 | 8.20 | " " " .... | ...... | .... |
| " 28 | 336.0 | 29.0 | " | 15.576 | ...... | 2.430 | .552 | 11.00 | Nearly clear; yellowish; slight odor ...... | 21.07 | .26 |
| Mar. 4 | 296.0 | 15.0 | " | 7.434 | ...... | 1.075 | .555 | 9.60 | Clear; earthy odor .... | ...... | .... |
| " 7 | 336.0 | 96.4 | " | 9.735 | ...... | 1.322 | .570 | 14.47 | Slightly turbid; od'rless | 38.85 | .57 |
| Mean.. | 331.0 | 26.9 | .510 | 12.860 | ...... | 1.637 | .549 | 9.611 | | | |

* Observer, Dr. F. Brendel, Peoria.

TABLE XV.—PEORIA (Hydrant.)

| Date. 1888. | | Total Solids... | Suspended matter....... | Nitrogen in Nitrates...... | Chlorine....... | Hardness $CaCO^3$........ | Free Ammonia | Alb. Ammonia | Oxygen consumed....... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|---|
| May | 21 | 356.9 | 19.5 | 1.130 | 27.61 | 214.8 | .076 | .330 | 8.00 | Nearly colorless; odorless ....... |
| " | 28 | 457.9 | 132.0 | .945 | 23.567 | 224.4 | .066 | .440 | 8.88 | Turbid with slight earthy odor.. |
| June | 5 | 319.8 | 25.5 | 1.320 | 14.726 | 187.2 | .031 | .350 | 8.20 | Turbid; yellowish; odorless ..... |
| July | 3 | 330.4 | 15.6 | .567 | 24.780 | 243.0 | .082 | .482 | 8.96 | Clear; yellowish; odorless........ |
| " | 10 | 281.0 | 37.0 | 1.658 | 21.240 | 180.0 | .034 | .420 | 8.32 | Slightly turbid; odorless.......... |
| " | 17 | 292.4 | 18.0 | 1.008 | 19.586 | 198.0 | .108 | .398 | 10.16 | " " " .......... |
| " | 24 | 265.7 | 24.0 | .315 | 19.232 | 178.0 | .033 | .490 | 11.18 | Nearly clear; yellowish; earthy odor .................................. |
| Aug. | 1 | 296.6 | 21.0 | .630 | 20.765 | 186.0 | .131 | .664 | 10.80 | Nearly clear; yellowish; odorless |
| " | 8 | 301.0 | 8.0 | 2.394 | 27.728 | 218.0 | .133 | .376 | 5.72 | Clear; yellowish; slight earthy odor.................................. |
| " | 14 | 325.0 | 11.0 | 2.079 | 31.976 | 198.0 | .092 | .376 | 8.88 | Opalescent; yellowish; earthy odor.................................. |
| Sept. | 18 | 323.0 | 12.4 | .520 | 35.400 | 208.0 | .071 | .396 | 6.56 | Nearly clear; odorless............ |
| " | 25 | 333.2 | 22.2 | trace | 43.658 | 194.0 | .060 | .410 | 7.20 | Nearly clear; slight odor......... |
| Oct. | 2 | 347.8 | 17.1 | trace | 43.240 | 224.0 | .208 | .384 | 6.00 | Opalescent: odorless.............. |
| " | 9 | 348.0 | 15.2 | trace | 43.188 | 240.0 | .098 | .340 | 7.125 | Clear and odorless................ |
| Mean . | | 327.7 | 27.4 | .897 | 28.334 | 206.6 | .087 | .397 | 8.184 | |

The results are given in Tables XIV and XV. These show considerable differences between the inlet and hydrant water and not always in favor of the latter. The excess of chlorides in the hydrant water is especially noteworthy, which suggests a contamination with salt from some source. It is said that there is a break in the pipe near the shore and at a point where contaminated water could be drawn. Part of the overflow from an artesian well enters the river near where the break is supposed to exist, and besides this a ditch, which serves as a drain for a part of the city, discharges its contents at the same point.

As regards organic matter, as indicated by consumption of oxygen and albuminoid ammonia found, the Peoria tests seem to show a worse instead of a better condition of affairs than at Henry. There is an increase in suspended matter and nitrates, but a marked decrease in chlorides. This latter must be largely attributed to dilution and it gives us roughly a measure of its amount. The weather-bureau observations show an excessive rainfall at Peoria, sufficient, I think, to account for this dilution.

Taking this into consideration it is plain that the water of Peoria Lake must be contaminated to no small extent. The samples were taken, as mentioned above, near the outer end of the inlet pipe which supplies the city. This was supposed to be beyond danger of contamination by local causes, but a personal inspection in November convinced me that this is far from being the case. A portion of the city sewage flows into the lake and in addition to this, the drainage from the large glucose factories and distilleries. A portion of this drainage is *clean*, consisting of the slops from the grain. It is, however, largely nitrogenous and soon begins to putrefy thus becoming an active source of contamination. In some of the large distilleries, during the period under examination, this slop was not discharged into the lake but was fed to cattle. I am informed that 15,000 head were fed there during the summer, and that 2,500,000 bushels of grain was mashed. This number of cattle was increased to 26,000 during the colder months.

As the drainage from all the cattle sheds passes immediately into the lake, the explanation of its contamination is not difficult. With the wind from the south a portion of this filth drifts even beyond the point where the water supply is taken.

The effect of this contamination is shown in a marked degree at Pekin, 10 miles below. With an increase in albuminoid ammonia we have a three-fold increase in free ammonia, both reaching 1 part per 1,000,000 on several occasions during the summer, as shown in Table XVI. During the winter the excess of albuminoid ammonia over that found at the upper bridge is quite marked.

TABLE XVI. PEKIN (River.)

| Date. 1888. | | Total Solids | Suspended matter | Nitrogen in Nitrates | Chlorine | Hardness CaO | Free Ammonia | Alb. Ammonia | Oxygen consumed | Physical Conditions. | *Mean temperature week ending | *Total rainfall week ending |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| May | 21 | 329.7 | 21.3 | .882 | 11.560 | 218.4 | .186 | .502 | 6.560 | Nearly clear; odorless. | 55.00 | .29 |
| " | 28 | 1010.9 | 704.3 | .567 | 7.434 | 219.6 | .221 | .922 | 22.400 | Very turbid; odorless. | 68.85 | 5.75 |
| June | 4 | 328.0 | 79.5 | .819 | 4.325 | 162.0 | .296 | .465 | 7.560 | Turb'd; odorless...... | 63.85 | .13 |
| " | 11 | 302.9 | 54.0 | 1.197 | 3.960 | 168.0 | .326 | .456 | 7.440 | Slightly turbid; earthy odor.................. | 72.10 | .... |
| July | 16 | 258.4 | 48.1 | 1.197 | 5.660 | 148.0 | .331 | .526 | 9.680 | Opalescent; yellowish; earthy odor .......... | 72.85 | .30 |
| " | 23 | 280.5 | 49.2 | .370 | 7.196 | 158.0 | .256 | .500 | 9.840 | Opalescent; yellowish; earthy odor .......... | 77.00 | .... |
| " | 30 | 275.0 | 42.1 | .210 | 8.850 | 172.0 | .332 | .816 | 12.720 | Opalescent; yellowish; earthy odor .......... | 81.57 | 3.00 |
| Aug. | 7 | 263.5 | 19.5 | trace | 12.390 | 200.0 | .564 | .612 | 7.520 | Slight turbidity; yellowish; odorless ..... | 79.85 | .50 |
| " | 13 | 314.9 | 47.0 | .200 | 14.160 | 198.0 | .352 | .604 | 9.920 | Opalescent; earthy odor; yellowish...... | 68.50 | .38 |
| Sept. | 17 | 290.0 | 17.2 | 2.016 | 19.470 | 201.0 | 1.334 | .690 | 8.800 | Slightly turbid; strong earthy odor.......... | 61.70 | 1.17 |
| " | 24 | 305.0 | 47.7 | .960 | 19.586 | 208.0 | .966 | 1.172 | 9.760 | Slightly turbid; strong earthy odor.......... | 64.14 | 1.00 |
| Oct. | 1 | 368.8 | 65.2 | .504 | 23.718 | 240.0 | .972 | .858 | 9.040 | Opalescent; odorless .. | 53.00 | .00 |
| " | 8 | 364.0 | 39.0 | 1.250 | 26.666 | 260.0 | .888 | .804 | 7.760 | Nearly clear; earthy odor. ................. | 51.14 | .50 |
| " | 15 | 328.0 | 31.1 | trace | 25.844 | 252.0 | .856 | .536 | 8.000 | Nearly clear; earthy odor.................. | 51.30 | .03 |
| " | 22 | 339.2 | 40.6 | 1.396 | 32.760 | 246.0 | 1.320 | .556 | 6.800 | Slightly turbid; yellowish; earthy odor . | 46.00 | 1.62 |
| " | 29 | 319.2 | 43.3 | 1.134 | 31.860 | 224.0 | .820 | .382 | 6.720 | Nearly clear; earthy odor.................. | 50.83 | .25 |
| Mean . | | 353. | 84.3 | .795 | 16.152 | 204.6 | .645 | .650 | 9.410 | | | |
| 1889. | | | | | | | | | | | | |
| Feb. | 4 | 357.6 | 22.8 | 1.898 | 16.753 | ...... | 1.690 | .962 | 9.80 | Cattle shed odor; nearly clear .......... | 36.00 | .05 |
| " | 11 | 341.4 | 8.0 | trace | 11.670 | ...... | 1.620 | 1.160 | 9.90 | Cattle shed odor; nearly clear .......... | 22.85 | .10 |
| " | 19 | 357.4 | 21.5 | 3.100 | 16.520 | ...... | 1.710 | 1.146 | 21.90 | Cattle shed odor; opalescent ............ | 32.85 | 1.55 |
| " | 25 | 372.0 | 16.5 | 2.560 | 11.682 | ...... | 1.810 | .896 | 9.80 | Strong cattle odor; nearly clear .......... | 15.83 | .35 |
| Mar. | 4 | 356.0 | 62.4 | trace | 8.496 | ...... | 1.826 | 1.056 | 11.10 | Strong cattle odor; opalescent ............ | 36.10 | 1.10 |
| " | 11 | 328.0 | 129.7 | .00 | 5.664 | ...... | .890 | .870 | 176.50 | Strong cattle odor; turbid.... .............. | 36.50 | .00 |
| Mean.. | | 352.0 | 43.5 | 1.259 | 11.792 | ...... | 1.591 | 1.015 | 13.358 | | | |

The increase in free and albuminoid ammonia and oxygen consumption is very marked in the winter tests at Pekin. The odor of the water was unmistakable and suggested at once the nature of the contamination.

The increase in suspended matter in March is due to the dilution with dirty water washed down by melting snow and ice.

A consideration of Tables XVII, XVIII, XX, XXI, and XXII will show the condition of the river below Pekin. Table XIX embraces results obtained by analysis of the water of the Sangamon River collected at Chandlerville.

* Observer, J. E. Terborg, Pekin.

TABLE XVII.—COPPERAS CREEK (Illinois River).

| Date. 1888. | | Total Solids… | Suspended matter…… | Nitrogen in Nitrates…… | Chlorine…… | Hardness $CaCO_3$…… | Free Ammonia | Alb. Ammonia. | Oxygen consumed…… | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|---|
| May | 16 | 297.5 | 19.3 | .220 | 10.550 | 208.8 | .102 | .724 | 15.040 | Turbid; earthy odor.............. |
| June | 20 | 293.2 | 46.2 | .379 | 4.720 | 229.0 | .192 | .480 | 8.800 | Slightly turbid; yellowish; earthy odor.............................. |
| July | 4 | 299.9 | 43.5 | .095 | 9.912 | 202.0 | .196 | .760 | 10.280 | Yellowish; earthy odor........... |
| " | 11 | 523.7 | 326.7 | 1.197 | 3.894 | 158.0 | .144 | .644 | 13.920 | Very turbid; earthy odor........ |
| " | 18 | 247.5 | 41.2 | 1.386 | 5.841 | 160.0 | .166 | .357 | 8.400 | Opalescent; yellow; earthy odor |
| " | 25 | 242.9 | 27.5 | .125 | 8.496 | 190.0 | .275 | .394 | 10.560 | " " " " |
| Aug. | 15 | 330.0 | 40.9 | .620 | 7.904 | 204.0 | .386 | .466 | 9.120 | Nearly clear; yellow; earthy odor |
| " | 24 | 292.5 | 41.9 | trace | 9.660 | 192.0 | .020 | .660 | 9.760 | Nearly clear; organic odor; yellowish.......................... |
| Sept. | 19 | 276.2 | 22.0 | ...... | 16.638 | 220.0 | .166 | .760 | 6.960 | Nearly clear; organic odor; yellowish.......................... |
| " | 26 | 313.0 | 26.2 | ...... | 19.647 | 212.0 | .270 | .723 | 17.840 | Nearly clear; odorless; floating organic matter.................. |
| Mean. | | 311.6 | 63.5 | .402 | 9.726 | 197.5 | .191 | .596 | 11.068 | |

TABLE XVIII.—HAVANA (Illinois River).

| Date. | | Total Solids | Suspended matter | Nitrogen in Nitrates | Chlorine | Hardness $CaCO_3$ | Free Ammonia | Alb. Ammonia | Oxygen consumed | Physical Conditions |
|---|---|---|---|---|---|---|---|---|---|---|
| 1888. | | | | | | | | | | |
| May | 17 | 308.0 | 19.0 | .126 | 11.780 | 237.0 | .048 | .645 | 11.760 | Slight color; unusual odor....... |
| " | 24 | 321.3 | 21.4 | .504 | 10.620 | 233.9 | .494 | .346 | 8.160 | Clear; earthy odor................ |
| " | 31 | 465.9 | 274.7 | .346 | 5.310 | 182.4 | .086 | .700 | 13.720 | Muddy; earthy odor............... |
| June | 7 | 290.0 | 56.2 | .819 | 3.860 | 198.0 | .220 | .389 | 8.160 | Slightly turbid; yellowish; odorless.............................. |
| " | 14 | 283.2 | 21.0 | .630 | 4.177 | 204.0 | .186 | .380 | ...... | Slightly turbid; yellowish; odorless.............................. |
| " | 21 | 312.4 | 45.6 | .250 | 6.584 | 200.0 | .270 | .424 | 9.800 | Yellowish; earthy odor...... .... |
| " | 28 | 310.5 | 32.2 | trace | 5.876 | 224.0 | .323 | .426 | 9.760 | Opalescent; earthy odor.......... |
| July | 5 | 292.0 | 23.7 | .819 | 10.372 | 246.0 | .207 | .500 | 9.440 | Nearly clear; odorless; slightly yellow.......................... |
| " | 12 | 318.8 | 128.9 | 1.449 | 4.708 | 144.0 | .036 | .414 | 10.560 | Very turbid; odorless............ |
| " | 19 | 251.9 | 20.4 | .630 | 5.664 | 160.0 | .146 | .334 | 8.480 | Nearly clear; odorless............ |
| " | 26 | 243.5 | 12.5 | trace | 5.320 | 192.0 | .121 | .380 | 8.720 | Nearly clear; yellowish; earthy odor.............................. |
| Aug. | 2 | 251.5 | 31.8 | .160 | 7.080 | 172.0 | .362 | .430 | 9.040 | Nearly clear; yellowish; earthy odor.............................. |
| " | 9 | 283.4 | 42.3 | .500 | 8.729 | 188.0 | .452 | .412 | 8.540 | Nearly clear; yellowish; earthy odor.............................. |
| " | 16 | 321.4 | 62.0 | .580 | 10.974 | 196.0 | .340 | .400 | 8.400 | Slightly turbid; yellowish; earthy odor.............................. |
| " | 23 | 309.3 | 44.4 | .740 | 17.524 | 190.0 | .610 | .576 | 8.800 | Opalescent; yellow; earthy odor. |
| " | 30 | 284.8 | 41.7 | 2.646 | 23.360 | 214.0 | .384 | .474 | 7.680 | Slight earthy odor................ |
| Sept. | 6 | 268.5 | 28.5 | 1.325 | 13.456 | 200.0 | .546 | .442 | 9.520 | Opalescent; yellowish; earthy odor.............................. |
| " | 13 | 274.2 | 37.8 | .630 | 11.646 | 198.0 | .496 | .426 | 7.600 | Nearly clear; earthy odor........ |
| " | 20 | 304.0 | 32.2 | 1.008 | 12.380 | 204.0 | .458 | .468 | 7.520 | Nearly clear; odorless............ |
| " | 27 | 253.0 | 27.5 | 2.500 | 10.620 | 202.0 | .480 | .384 | 6.880 | " " " |
| *Oct. | 4 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | .............................. |
| " | 11 | 281.0 | 33.9 | trace | 22.656 | 220.0 | .976 | .408 | 6.800 | Nearly clear; slight earthy odor. |
| " | 18 | 288.4 | 10.5 | .882 | 19.292 | 225.0 | .530 | .310 | 3.680 | Nearly clear; odorless............ |
| " | 25 | 354.0 | 17.7 | 1.008 | 20.178 | 256.0 | .406 | .322 | 6.960 | Nearly clear; earthy odor........ |
| Nov. | 1 | 371.8 | 25.3 | trace | 25.842 | 216.0 | .040 | .330 | 5.440 | " " " " |
| Mean... | | 301.78 | 45.4 | .731 | 11.583 | 204.2 | .342 | .430 | 8.142 | |
| 1889. | | | | | | | | | | |
| Jan. | 14 | 328.5 | 50.0 | .000 | 16.496 | ...... | 1.626 | .375 | 8.600 | Nearly clear; odorless............ |
| " | 21 | 305.5 | 25.5 | trace | 8.260 | ...... | .642 | .310 | 6.920 | " " ............ |
| " | 28 | 317.0 | 24.7 | 1.20 | 9.416 | ...... | 1.026 | .440 | 5.120 | " " ............ |
| Feb. | 4 | 331.0 | 67.8 | .750 | ........ | ...... | .773 | .730 | 7.400 | Slightly turbid; earthy odor..... |
| " | 11 | 312.0 | 21.7 | 1.180 | 9.086 | ...... | .845 | .561 | 9.600 | Nearly clear; slight earthy odor. |
| " | 18 | 351.0 | 24.7 | .125 | 16.166 | ...... | .820 | .604 | 9.100 | Nearly clear; cattle odor......... |
| " | 25 | 317.4 | 13.8 | .481 | 7.788 | ...... | 1.015 | .523 | 7.500 | " " " ........ |
| Mar. | 4 | 432.0 | 209.0 | trace | 7.430 | ...... | 1.020 | .692 | 14.42 | Muddy; strong odor .............. |
| " | 11 | 477.0 | 289.8 | " | 8,850 | ...... | 1.940 | 1.008 | 14.45 | " " .............. |
| Mean. | | 352.4 | 80.8 | .414 | 9.277 | ...... | 1.078 | .585 | 9.234 | |

* Jug broken in transit.

## Table XIX.—Chandlerville (Sangamon River.)

| Date. 1888. | | Total Solids... | Suspended matter....... | Nitrogen in Nitrates ...... | Chlorine...... | Hardness $CaCO^3$....... | Free Ammonia | Alb. Ammonia. | Oxygen consumed...... | Physical Conditions. | *Mean temperature — week ending....... | *Total rainfall week ending. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| July | 10 | 385.0 | 141.0 | 2.016 | 1.876 | 208. | .060 | .322 | 5.800 | Turbid; odorless....... | 76.28 | 3.48 |
| " | 17 | 301.7 | 68.3 | .900 | 9.583 | 186. | .049 | .490 | 12.040 | Turbid; earthy odor... | 71.64 | .77 |
| " | 24 | 334.9 | 79.0 | 1.134 | 2.124 | 226. | .010 | .220 | 3.200 | Cloudy; yellowisn; odorless.............. | 74.00 | .00 |
| Aug. | 1 | 330.8 | 134.5 | .630 | 3.065 | 142. | .031 | .400 | 7.200 | Turbid; odorless....... | 79.64 | .34 |
| " | 8 | 298.9 | 43.0 | .557 | 2.832 | 250. | .048 | .218 | 3.760 | Slight cloudiness; odorless.............. | 74.28 | .91 |
| " | 15 | 274.8 | 48.2 | .560 | 2.357 | 192. | .084 | .222 | 4.960 | Opalescent; earthy od'r | 66.85 | .09 |
| " | 23 | 307.4 | 28.7 | trace | 3.540 | 242. | .134 | .172 | 3.680 | Nearly clear; slight earthy odor.......... | 67.71 | .08 |
| Sept. | 3 | 309.5 | 23.0 | .250 | 3.500 | 250. | .010 | .240 | 3.200 | Nearly clear; earthy odor.................. | 65.28 | .12 |
| Mean.... | | 317.8 | 70.7 | .755 | 3.609 | 212. | .053 | .285 | 5.480 | | | |

## Table XX.—Beardstown.

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| May | 21 | 320.2 | 42.2 | 1.320 | 7.67 | 216.0 | .368 | .382 | 7.52 | Slightly yellowish; odorless ................ | 54.06 | 1.39 |
| " | 28 | 561.7 | 322.4 | .630 | 6.112 | 212.4 | .256 | .540 | 9.520 | River high; very turbid | 67.96 | 2.28 |
| June | 4 | 325.5 | 131.0 | .120 | 3.186 | 170.4 | .176 | .428 | 9.920 | Muddy; odorless....... | 60.45 | .00 |
| " | 11 | 359.9 | 138.5 | .693 | 3.540 | 154.0 | .190 | .474 | 8 80 | Turbid; yellowish; earthy odor. ......... | 70.92 | 1.05 |
| " | 18 | 322.8 | 79.4 | ...... | 3.185 | 205.0 | .086 | .422 | 8.16 | Nearly clear; odorless. | 75.21 | .69 |
| " | 25 | 367.6 | 95.7 | .120 | 3.540 | 227.0 | .142 | .386 | 8.80 | Turbid; yellowish; earthy odor........... | 75.48 | 3.49 |
| July | 2 | 386.5 | 162.8 | .350 | 4.141 | 204.0 | .110 | .410 | 8.640 | Turbid; earthy odor... | 72.36 | 1.31 |
| " | 9 | 308.9 | 119.9 | .882 | 8.850 | 170.0 | .141 | .430 | 9.520 | " " " .. | 79.50 | 3.02 |
| " | 16 | 281.1 | 83.4 | .440 | 3.656 | 166.0 | .108 | .352 | 7.760 | Slightly turbid; earthy odor.................. | 73.96 | .72 |
| " | 23 | 236.3 | 38.5 | .252 | 2.357 | 150.0 | .092 | .334 | 7.000 | Cloudy; earthy odor... | 73.51 | .67 |
| " | 30 | 290.3 | 79.8 | .105 | 3.540 | 176.0 | .122 | .310 | 7.360 | Turbid; yellowish; earthy odor. ......... | 80.30 | 1.67 |
| Aug. | 6 | 321.0 | 89.7 | .252 | 5.780 | 200.0 | .256 | .356 | 5.840 | Turbid; earthy odor .. | 79.74 | 1.28 |
| " | 13 | 425.7 | 174.6 | .380 | 6.372 | 184.0 | .307 | .440 | 8 800 | " odorless .. .... | 68.41 | .10 |
| " | 20 | 304.4 | 61.0 | .560 | 8.496 | 196.0 | .190 | .510 | 6.640 | " " ...... | 74.22 | .20 |
| " | 28 | 318.5 | 60.8 | trace | 9.420 | 202.0 | .142 | .330 | 7.280 | Nearly clear; odorless; yellowish ............ | 68.85 | .56 |
| Sept. | 3 | 298.5 | 49.3 | 1.512 | 6.606 | 210.0 | .222 | .336 | 5.540 | Slightly turbid; earthy odor.................. | 65.80 | .06 |
| " | 10 | 282.0 | 37.5 | 1.008 | 10.620 | 216.0 | .216 | .330 | 7.520 | Slightly turbid; earthy odor.................. | 69.89 | .16 |
| " | 17 | 302.8 | 41.8 | ...... | 8.850 | 220.0 | .324 | .508 | 8.500 | Slightly turbid; earthy odor.................. | 60.26 | .99 |
| " | 24 | 297.2 | 43.3 | .504 | 12.623 | 230.0 | .280 | .384 | 5.280 | Opalescent; odorless... | 63.52 | .79 |
| Oct. | 1 | 273.4 | 24.8 | 1.000 | 7.256 | 235.0 | .191 | .408 | 7.200 | " " .. | 55.02 | .00 |
| " | 8 | 308.2 | 34.0 | 1.200 | 14.276 | 230.9 | .260 | .276 | 4.880 | Nearly clear; earthy odor.................. | 52.08 | .83 |
| " | 15 | 359.0 | 70.4 | 2.208 | 2.336 | 258.0 | .248 | .334 | 6.00 | Slightly opalescent; slight earthy odor.... | 51.65 | .09 |
| " | 22 | 287.0 | 34.5 | 1.512 | 19.401 | 256.0 | .274 | .262 | 5.44 | Nearly clear; odorless. | 47.04 | .83 |
| " | 29 | 317.2 | 15.5 | trace | 17.70 | 230.0 | .160 | .188 | 4.66 | " " " | 51.36 | .31 |
| Mean . | | 390. | 84.7 | .62 | 7.524 | 204.9 | .202 | .380 | 7.354 | | | |

*These observations were made by Sergeant John Craig, Signal Service, U. S. A., Springfield.—J. H. R.

**TABLE XX.—BEARDSTOWN.—*Continued.***

| .te. | Total Solids... | Suspended matter...... | Nitrogen in Nitrates...... | Chlorine...... | Hardness $CoCO^3$...... | Free Ammonia | Alb. Ammonia. | Oxygen consumed...... | Physical Conditions. | *Mean temperature, week ending...... | *Total rainfall week ending. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 89. | | | | | | | | | | | |
| 14 | 314.1 | 59.0 | .66 | 7.08 | ...... | .506 | .256 | 6.300 | Slightly turbid; odorless.................... | 28.00 | 1.65 |
| 21 | 329.2 | 46.5 | 1.134 | 10.652 | ...... | .238 | .372 | 4.640 | Slightly turbid; odorless.................... | 29.27 | .61 |
| 28 | 341.2 | 97.0 | 1.960 | 4.070 | ...... | .300 | .222 | 4.640 | Slightly turbid; odorless.................... | 30.40 | .00 |
| 4 | 310.0 | 40.0 | .665 | 4.460 | ...... | .242 | .342 | 4.70 | Opalescent; earthy od'r | 32.02 | .00 |
| 11 | 316.4 | 43.0 | trace | 10.381 | ...... | .335 | .560 | 5.70 | " " " | 23.58 | .09 |
| 25 | 296.0 | 52.3 | 1.380 | 4.956 | ...... | 2.950 | .390 | 7.100 | " " " | 28.83 | .37 |
| ean.. | 317.8 | 56.3 | .966 | 6.933 | ...... | .762 | .357 | 5.505 | | | |

**†TABLE XXI.—ILLINOIS RIVER AT ALTON R. R. CROSSING NEAR PEARL.**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 88. | | | | | | | | | | ‡ | ‡ |
| e 16 | 658.8 | 431.8 | 1.134 | 3.540 | 204.0 | .058 | .630 | 11.36 | Muddy; earthy odor .. | 75.28 | .59 |
| 23 | 1134.4 | 918.0 | trace | 3.55 | 208.0 | .091 | .661 | 18.88 | Muddy.................. | 78.64 | 2.62 |
| 30 | 670.0 | 458.9 | .190 | 3.58 | 206.0 | .012 | .600 | 7.76 | " .................. | 75.64 | 1.56 |
| 7 | 447.8 | 214.2 | 1.134 | 5.416 | 218.0 | .076 | .458 | 12.00 | Very turbid; earthy odor.................. | 84.64 | .55 |
| 11 | 386.7 | 139.7 | 1.768 | 6.842 | 196.0 | .075 | .426 | 10.560 | Muddy; odorless....... | 75.42 | 2.24 |
| 18 | 363.4 | 121.7 | .485 | 6.726 | 210.0 | .028 | .340 | 61.400 | Muddy; earthy odor .. | 76.00 | .05 |
| 25 | 339.7 | 92.5 | 1.323 | 5.310 | 190.0 | .016 | .358 | 7.000 | Slight turbidity; slight earthy odor.......... | 71.71 | .61 |
| t. 1 | 326.9 | 68.4 | .940 | 7.434 | 224.0 | .078 | .396 | 8.000 | Slight turbidity; odorless.................. | 70.80 | .60 |
| 8 | 295.4 | 34.7 | 1.134 | 8.275 | 202.0 | .030 | .430 | 6.720 | Opalescent; odorless; yellowish............ | 68.93 | .01 |
| 15 | 312.0 | 42.7 | .505 | 11.646 | 206.0 | .022 | .348 | 6.800 | Opalescent; odorless .. | 68.35 | .40 |
| 22 | 304.0 | 60.2 | trace | 8.674 | 196.0 | .129 | .342 | 6.000 | " " ... | 66.00 | 2.76 |
| 29 | 282.0 | 33.3 | .756 | 12.036 | 240.0 | .127 | .420 | 7.040 | " " ... | 59.50 | .00 |
| 6 | 290.0 | 50.0 | .630 | 11.890 | 220.0 | .102 | .386 | 4.810 | " " ... | 56.80 | .47 |
| 13 | 296.6 | 21.2 | 1.386 | 16.284 | 205.0 | .057 | .302 | 5.680 | Slightly opalescent; odorless............... | 54.00 | .10 |
| 20 | 325.4 | 38.7 | trace | 12.376 | 240.0 | .061 | .366 | 4.720 | Slightly turbid; odorless.................. | 53.80 | .56 |
| 27 | 295.2 | 34.5 | trace | 15.930 | 250.0 | .118 | .286 | 5.120 | Nearly clear; odorless. | 50.00 | .70 |
| ean . | 402.5 | 172.5 | .711 | 8.719 | 213.4 | .067 | .422 | 7.653 | | | |

* These are means of observations made by P. J. Hasenstab at Jacksonville, and by Eastman at Griggsville.—J. H. R.

‡ These observations were made by P. J. Bates, Whitehall.—J. H. R.

† Mean temperature by months, at Kampsville, Calhoun Co., precipitation, and days n which rain fell.

Temperature—May, 63°.7; June, 75°.8; July, 80°.3; August, 73°.6; Precipitation in inches, r, 6.12; June, 6.53; July, 3.75; August, 5.20. Days of rain, May, 2, 7, 8, 15, 18, 24, 26, 28; June 5, ), 10, 22, 24, 25, 27; July 4, 7, 8, 9, 22, 25, 26, 27; August 4, 6, 7, 17, 20, 21, 25, 26. Dr. Southworth, erver.—J. H. R.

**Table XXII.—Grafton (Near Mouth Illinois River).**

| Date. 1888. | | Total Solids... | Suspended matter...... | Nitrogen in Nitrates...... | Chlorine...... | Hardness $CaCO_3$...... | Free Ammon'a | Alb. Ammonia. | Oxygen consumed...... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|---|
| June | 20 | 321.9 | 94.0 | .550 | 4.106 | 210.0 | .094 | .360 | 8.320 | Turbid; odorless.................. |
| " | 27 | 290.5 | 97.6 | .283 | 3.280 | 178.0 | .108 | .464 | 8.000 | Odorless; turbid.................. |
| July | 3 | 313.7 | 65.6 | .431 | 3.540 | 208.0 | .037 | .406 | 7.520 | Slightly turbid; odorless.......... |
| " | 12 | 297.9 | 67.6 | trace | 6.018 | 178.0 | .025 | .470 | 8.560 | Very strong and disagreeable |
| " | 18 | 274.6 | 60.7 | .442 | 3.773 | 168.0 | .138 | .390 | 8.640 | odor; not natural................ |
| | | | | | | | | | | Slightly turbid; odorless.......... |
| Sept. | 12 | 294.2 | 36.0 | ...... | 5.522 | 205.0 | .020 | .810 | * | Vinegar odor; bad jug............ |
| " | 19 | 273.2 | 33.0 | ...... | 11.328 | 218.0 | .070 | .636 | 14.400 | Floating matter; jug not clean.. |
| " | 26 | 284.4 | 36.4 | 1.386 | 13.270 | 210.0 | .043 | .486 | 7.200 | Odorless; nearly clear............ |
| Oct. | 3 | 294.4 | 20.7 | .500 | 12.390 | 222.0 | .094 | .344 | 4.800 | " " " ............ |
| " | 10 | 356.0 | 38.3 | 1.00 | 10.620 | 240.0 | .200 | .840 | ...... | Opalescent; (whisky jug).......... |
| " | 17 | 334.6 | 29.2 | 1.260 | 17.636 | 220.0 | .164 | .342 | ...... | " " ......... |
| " | 24 | 284.4 | 25.2 | 1.134 | 18.980 | 252.0 | .156 | .248 | 5.360 | Nearly clear; earthy odor........ |
| Mean. | | 301.6 | 50.3 | .582 | 9.205 | 242.4 | .095 | .483 | 7.300 | |
| 1889. | | | | | | | | | | |
| Jan. | 14 | 499. | 47.0 | .42 | 126.236 | ...... | 1.138 | .414 | 6.16 | Opalescent; earthy odor......... |
| " | 21 | 367.2 | 104.5 | .367 | 33.90 | ...... | .870 | .339 | 6.16 | Opalescent; odorless.............. |
| " | 28 | 418. | ...... | .000 | 10.62 | ...... | .290 | .866 | 7.36 | Turbid; odorless.................. |
| Feb. | 4 | 355. | 110. | .000 | 5.905 | ...... | .450 | .652 | 6.48 | Turbid; organic odor.............. |
| " | 11 | 291.4 | 8.4 | .000 | 8.614 | ...... | .450 | .666 | 3.50 | Clear; organic odor................ |
| " | 18 | 353. | 44.5 | trace | 8.260 | ...... | .554 | .310 | 7.50 | Nearly clear; earthy odor........ |
| " | 25 | 359. | 8.8 | .000 | 7.580 | ...... | .550 | .560 | 16.60 | Clear, organic odor................ |
| Mar. | 4 | 720.5 | ...... | trace | 5.900 | ...... | 1.10 | 1.560 | 15.28 | Very muddy......................... |
| " | 11 | 334.0 | 78.5 | .000 | 5.782 | ...... | 2.47 | 1.135 | 14.320 | Turbid; organic odor.............. |
| Mean. | | 410.8 | 44.6 | .087 | 23.644 | ...... | .875 | .722 | 9.818 | |

During the earlier months high water made the results very irregular, with generally increased organic matter. On the whole, there seems to be no important change below Havana during the latter part of the summer, and it appears we reach here a condition in the river where the organic matter is very slowly changed. I have already referred to the organic matter remaining in a stream after a flow of a long distance as belonging, in all probability, to a very stable type. In the work of 1886 the portion of this residue left to be oxidized by the laboratory process was very much smaller than that left in 1888, and the reason for this difference can be found largely in the difference of temperature of the two seasons. The condition of the lower Illinois is, as regards residual organic matter, but little different from that of the Kankakee, Fox, Big Vermilion, or Little Vermilion, and I think we reach here the limit of oxidation practically possible under the conditions of temperature and dilution which obtained during the season.

The winter tests show many irregularities, but in general a less rapid rate of destruction of organic matter than during the summer. The condition of the water at Beardstown is apparently much modified by the flow from the Sangamon as the tests below this point indicate again an increase of albuminoid ammonia.

The water at Pearl was not in suitable condition for analysis until late in the summer. It was muddy until the middle of August, and, as the chlorine tests indicate, very greatly diluted by heavy rains and probably with backwater from the Mississippi. At Grafton we have, of course, a similar condition of affairs, although the turbidity was in general less marked where the low chlorine shows the same dilution. Undoubtedly a large proportion of the water here came from the Mississippi.

The samples sent from Grafton on January 14 and 21, show a large amount of chlorine suggesting some sort of contamination which I cannot now account for.

The work of 1886-87 shows to what a remarkable degree oxidation is dependent on temperature, and the same fact is brought out in the winter work of this year, though in less marked degree. I am therefore led to believe that in a warm season quite different results would be obtained by an examination of the lower Illinois.

By comparison of the results obtained in different seasons we are enabled to draw an important conclusion which at first sight may appear singular. In considering the results obtained in the summer when a very rapid decrease in organic matter is observed after the large pollution at Bridgeport, it has been urged that most of this decrease must be due to sedimentation. If this were true, then we should expect the most rapid decrease where the conditions favoring sedimentation are the most perfect. We have these pefect conditions du ing the winter when the surface of the water is covered with ice, or at any rate not disturbed by navigation.

The analyses show us, beyond a doubt, that instead of there being a decrease in the amount of organic matter in the river and canal under these conditions, there is a very great increase. The oxidation and albuminoid ammonia tests show often as much as, or even more, organic matter at Joliet and Morris than at Bridgeport, and a very greatly amount, as compared with the summer tests, at other points down the stream.

Giving these observations due weight, I think we can effectually dispose of the objection urged f equently of late, and from quarters where more accurate information should be expected, that the purification of a stream polluted by sewage is chiefly a work of sedimentation rather than of bacterial or other oxidation. In the winter season sedimentation undoubtedly plays by far the most prominent part in the disappearance of pollution; but for the summer months the evidence points to something else as taking the first place. In employing the va ious oxidation tests or the albuminoid ammonia tests, it must be remembered that other indications near the source of a great contamination are probably below the truth, while in the same stream, a hundred or more miles away from this contamination, organic matters present are in a more suitable condition to respond to the tests. It seems true, therefore, that these methods do not exaggerate the extent of purification in flowing water.

## The Mississippi River.

Tables XXII to XXXII inclusive, give the results obtained by analysis of the water of the Mississippi river collected at East Dubuque, Rock Island, Quincy, Alton, St. Louis, East St. Louis, Chester and Cairo.

TABLE XXII.—EAST DUBUQUE.

| Date. | Total Solids... | Suspended matter....... | Nitrogen in Nitrates...... | Chlorine...... | Hardness CaCO³...... | Free Ammonia | Alb. Ammonia. | Oxygen consumed...... | Physica Conditions. | Mean temperature — week ending....... | T tal rainfall week ending. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Oct. 16 | 185.0 | 13.6 | ...... | 1.220 | 155. | .037 | .210 | 4.480 | Nearly clear; odorless. | ...... | .... |
| " 23 | 190.2 | 13.8 | ...... | 1.556 | 174. | .050 | .102 | 4.320 | " " " | ...... | .... |
| " 30 | 167.0 | 12.5 | ...... | 1.416 | 150. | .072 | .139 | 6.080 | " " " | ...... | .... |
| Mean.. | 180.7 | 13.3 | ...... | 1.397 | 159. | .053 | .150 | 4.960 | | | |

TABLE XXIII.—ROCK ISLAND.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sept. 17 | 207.4 | 47.0 | ...... | 1.168 | 142. | .062 | .328 | 6.800 | Slightly turbid; yellowish; odorless.......... | * 58.28 | * .59 |
| " 24 | 186.6 | 19.7 | ...... | 1.180 | 160. | .031 | .280 | 5.440 | Nearly clear; odorless | 58.85 | .77 |
| Oct. 1 | 189.0 | 23.2 | ...... | 1.649 | 150. | .054 | .200 | 4.800 | " " " | 52.28 | .00 |
| " 8 | 186.0 | 15.0 | ...... | 1.265 | 154. | .069 | .196 | 7.200 | " " " | 48.14 | .10 |
| Mean.. | 192.2 | 26.2 | ...... | 1.315 | 151. | .054 | .251 | 6.060 | | | |

TABLE XXIV.—QUINCY.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sept. 20 | 163.6 | 2.6 | ...... | 1.168 | 144. | .091 | .234 | 7.120 | Clear; odorless......... | ...... | .... |
| Oct. 11 | 197.0 | 22.0 | ...... | .930 | 150. | .049 | .312 | 5.060 | Opalescent; ordoi less. | ...... | .... |
| Mean.. | 180.3 | 12.3 | ...... | 1.049 | 147. | .070 | .273 | 6.090 | | | |

* Not enough water. † Mean of last 14.
*Observations U. S. Signal Service at Davenport.

TABLE XXV.—ALTON (River.)

| Date. 1888. | | Total Solids... | Suspended Matter...... | Nitrogen in Nitrates..... | Chlorine....... | Hardness $CaCO^3$...... | Free Ammonia | Alb. Ammonia. | Oxygen consumed...... | Physical Conditions. | †Mean temperature for month...... | Total rainfall week ending. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| July | 19 | 394.1 | 193.7 | .567 | 2.124 | 170. | .004 | .420 | 11.520 | Muddy.................. | 77.5 | 2.85 |
| Aug. | 2 | 299.7 | 132.1 | .316 | 2.357 | 150. | .031 | .434 | 8.000 | Muddy; earthy odor .. | 73.5 | .20 |
| " | 9 | 288.5 | 113.2 | ...... | 2.655 | 146. | .134 | .420 | 8.160 | Very turbid; odorless. | ...... | 2.11 |
| " | 15 | 288.5 | * | * | 4.071 | 164. | .060 | .422 | 8.800 | " " " | ...... | .00 |
| " | 23 | 408.0 | 217.4 | 1.197 | 1.295 | 160. | .024 | .396 | 8.000 | " " " | ...... | .90 |
| " | 30 | 273.1 | 85.2 | 1.260 | 6.370 | 166. | .020 | .316 | 7.520 | Nearly clear; odorless. | ...... | .12 |
| Sept. | 6 | 256.9 | 49.5 | ...... | 4.127 | 168. | .018 | .376 | 7.680 | " " " | 64.0 | .00 |
| " | 12 | 218.5 | 31.4 | ...... | 3.657 | 152. | .032 | .370 | 7.840 | " " " | ...... | .00 |
| " | 20 | 228.8 | 33.2 | ...... | 2.832 | 168. | .046 | .478 | 7.200 | " " " | ...... | .70 |
| " | 27 | 250.0 | 46.4 | ...... | 4.480 | 180. | .038 | .374 | 6.240 | " " " | ...... | 1.53 |
| Oct. | 4 | 247.6 | 54.5 | ...... | 3.540 | 180. | .061 | .366 | 6.900 | " " " | 53.2 | .00 |
| " | 11 | 238.6 | 26.4 | ...... | 6.726 | 180. | .095 | .262 | 6.400 | Slightly opalescent; odorless............... | ...... | .51 |
| " | 18 | 277.0 | 64.5 | ...... | 4.841 | 180. | .096 | .292 | 5.120 | Nearly clear; odorless. | ...... | .84 |
| " | 25 | 230.0 | 19.8 | ...... | 6.520 | 190. | .093 | .212 | 4.960 | " " " | ...... | .92 |
| Nov. | 1 | 275.0 | 61.7 | ...... | 5.664 | 188. | .066 | .202 | 6.000 | " " " | ...... | .00 |
| Mean . | | 278.6 | 75.2 | ...... | 4.083 | 169.4 | .166 | .356 | 7.356 | | | |
| 1889. | | | | | | | | | | | | |
| Jan. | 14 | 347.5 | 19.7 | .000 | 5.664 | ...... | .464 | .470 | 7.200 | Muddy; odorless....... | ...... | 1.25 |
| " | 21 | 339.4 | 20.9 | .88 | 5.876 | ...... | .452 | .428 | 7.040 | " " ...... | ...... | .12 |
| " | 28 | 324.4 | 19.1 | .65 | 4.062 | ...... | .518 | .306 | 5.120 | " " ...... | ...... | .02 |
| Feb. | 4 | 402.0 | 234.5 | 1.008 | ........ | ...... | .432 | .367 | 7.12 | Muddy; earthy odor... | ...... | .00 |
| " | 11 | 312.0 | 53.2 | trace | 5.664 | ...... | .420 | .296 | 5.520 | Slightly turbid; odorl's | ...... | .00 |
| " | 18 | 377. | 127.4 | trace | 5.651 | ...... | .438 | .404 | 7.200 | Muddy; odorless....... | ...... | 2.49 |
| " | 25 | 255. | 16.0 | trace | 5.310 | ...... | .340 | .251 | 6.100 | Opalescent; odorless.. | ...... | .45 |
| Mar. | 4 | 122.3 | ...... | trace | 8.614 | ...... | .316 | .651 | 15.2 | Very muddy; earthy odor.................... | ...... | 2.98 |
| Mean.. | | 309.9 | 61.3 | .317 | 5.834 | ...... | .422 | .396 | 7.562 | | | |

* Not enough water sent.

† Observations made by Dr. J. L. R. Wadsworth, at Collinsville.—J. H. R.

TABLE XXVI.—ALTON (Hydrant.)

| Date. 1888. | | Total solids... | Suspended matter...... | Nitrogen in Nitrates...... | Chlorine...... | Hardness $CaCO^3$...... | Free Ammonia | Alb. Ammonia | Oxygen consumed...... | Physical Conditions. | Mean temperature week ending...... | Total rainfall week ending. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| July | 20 | 726.7 | 482.2 | .567 | 5.133 | 160. | .084 | .552 | 13.12 | Muddy.................. | ...... | .... |
| Aug. | 3 | 268.8 | 45.5 | .200 | 1.062 | 180. | .023 | .278 | 7.120 | Turbid; odorless....... | ...... | .... |
| " | 10 | * | 32.1 | * | 3.540 | 166. | .118 | .260 | 6.960 | " " ...... | ...... | .... |
| " | 17 | 241.8 | 13.6 | .180 | 4.718 | 170. | .032 | .250 | 7.840 | Opalescent; odorless .. | ...... | .... |
| " | 24 | 272.4 | 45.3 | trace | 4.248 | 166. | .032 | .344 | 8.880 | Slightly turbid; earthy odor..................... | ...... | .... |
| " | 31 | 241.0 | 42.8 | 1.764 | 4.364 | 180. | .030 | .284 | 9.200 | Nearly clear; odorless. | ...... | .... |
| Sept. | 7 | 231.0 | 13.3 | ...... | 4.956 | 166. | .026 | .248 | 7.900 | " " " | ...... | .... |
| " | 13 | 262.6 | 68.5 | ...... | 2.938 | 168. | .098 | .360 | 6.320 | " " " | ...... | .... |
| " | 21 | 202.0 | 7.8 | ...... | 3.656 | 186. | .044 | .262 | 5.920 | Clear; odorless......... | ...... | .... |
| " | 28 | 291.2 | 75.0 | ...... | 4.070 | 190. | .048 | .366 | 5.200 | Opalescent; odorless... | ...... | .... |
| Oct. | 5 | 211.8 | 17.0 | ...... | 3.894 | 174. | .050 | .316 | 6.560 | Nearly clear; odorless. | ...... | .... |
| " | 12 | 219.0 | 35.2 | ...... | 4.956 | 160. | .107 | .203 | 5.120 | Opalescent; odorless... | ...... | .... |
| " | 19 | 229.6 | 24.5 | ...... | 5.787 | 176. | .123 | .172 | 3.680 | " " .. | ...... | .... |
| " | 26 | 211.4 | 36.0 | ...... | 6.018 | 184. | .053 | .188 | 5.040 | Nearly clear; odorless. | ...... | .... |
| Nov. | 2 | 216.2 | 10.3 | ...... | 4.620 | 170. | .084 | .132 | 4.400 | " " " | ...... | .... |
| †Mean . | | 238.3 | 33.3 | ...... | 4.202 | 174. | .062 | .261 | 6.438 | | | |

## Table XXVII.—St. Louis (River).

| te. 88. | Total Solids... | Suspended matter...... | Nitrogen in Nitrates.... | Chlorine...... | Hardness $CaCO_3$...... | Free Ammonia | Alb. Ammonia. | Oxygen consumed...... | Physical Conditions. | Mean temperature—week ending...... | Total rainfall week ending. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | 788.8 | 482.2 | ...... | 9.100 | 152. | .077 | .133 | 8.720 | Muddy; odorless....... | ...... | .... |
| 16 | 772.0 | ...... | ...... | 11.315 | 230. | .026 | .252 | 6.480 | " " ...... | ...... | .... |
| 23 | 784.0 | 511.0 | ...... | 9.027 | 232. | .022 | .266 | 6.000 | " " ...... | ...... | .... |
| 31 | ...... | ...... | ...... | ........ | ...... | .006 | .134 | ...... | " " ...... | ...... | .... |
| ean.. | 781.6 | 496.6 | ...... | 9.814 | 204. | .065 | .197 | 7.066 | | | |

## Table XXVIII.—St. Louis (Basin).

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 365.4 | ...... | ...... | 9.364 | 205. | .042 | .148 | 3.040 | Turbid; odorless....... | ...... | .... |
| 17 | 395.0 | ...... | ...... | 8.000 | 196. | .016 | .114 | 6.040 | " " ...... | ...... | .... |
| 23 | 444.8 | ...... | ...... | 9.204 | 210. | .048 | .142 | 3.920 | " " ...... | ...... | .... |
| 31 | ...... | ...... | ...... | ........ | ...... | .079 | .104 | ...... | " " ...... | ...... | .... |
| eah.. | 401.7 | ...... | ...... | 8.856 | 203. | .046 | .127 | 4.333 | | | |

## Table XXIX—East St. Louis.—(Two miles from pump house, river)

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| y 21 | 397.5 | 186.0 | ...... | 2.584 | .154 | .036 | .312 | 8.200 | Muddy; odorless....... | *75.14 | *1.49 |
| 28 | 332.6 | 146.5 | ...... | 3.656 | .148 | .031 | .202 | 8.240 | " " ...... | 79.00 | .33 |
| t. 15 | 407.4 | 157.7 | ...... | 4.956 | .198 | .028 | .316 | 5.920 | " " ...... | 63.14 | .06 |
| 22 | 350.2 | 158.6 | ...... | 5.664 | .176 | .069 | .384 | 6.000 | " " ...... | 66.14 | 1.25 |
| 6 | 261.4 | 29.0 | ...... | 4.364 | .184 | .110 | .302 | 5.360 | Slightly t'rbid; odorless | 55.71 | .46 |
| 13 | 252.0 | 24.8 | ...... | 4.248 | .204 | .049 | .224 | 4.480 | " " | 52.14 | .08 |
| 20 | 260.0 | 35.7 | ...... | 4.732 | .200 | .029 | .215 | 4.560 | " " | 52.7 | 1.29 |
| 27 | 257.0 | 24.8 | ...... | 5.510 | .224 | .020 | .168 | 3.680 | " " | 48.55 | .76 |
| ean . | 314.7 | 95.3 | ...... | 4.476 | .186 | .046 | .265 | 5.805 | | | |

## Table XXX.—East St. Louis—(Pump house.)

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| y 20 | 1742.5 | ...... | ...... | 2.594 | ...... | .054 | 1.130 | ...... | Very muddy ............ | ...... | .... |
| 27 | 1302.2 | ...... | ...... | 3.065 | ...... | .060 | .674 | ...... | " " ........... | ...... | .... |
| t. 15 | 428.0 | 198.3 | ...... | 4.602 | .167 | .028 | .324 | 4.480 | Muddy; odorless. ...... | ...... | .... |
| 22 | 347.0 | 137.2 | ...... | 5.310 | .188 | .054 | .344 | 5.600 | " " ...... | ...... | .... |
| 6 | 303.4 | 66.2 | ...... | 4.148 | .196 | .089 | .264 | 6.800 | Turbid; odorless ...... | ...... | .... |
| 12 | 284.6 | 39.2 | ...... | 5.890 | .180 | .049 | .222 | 4.460 | " " ...... | ...... | .... |
| 19 | 273.2 | 51.0 | ...... | 5.096 | .180 | .058 | .222 | 4.080 | " " ...... | ...... | .... |
| 26 | 255.4 | 50.3 | ...... | 4.956 | .180 | .050 | .158 | 4.640 | " " ...... | ...... | .... |
| ean . | 616.4 | 67.7 | ...... | 4.457 | .136 | .055 | .417 | 3.757 | | | |

## Table XXXI.—Chester.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | 414.6 | 191.2 | ...... | 6.200 | .185 | .065 | .246 | 4.800 | Muddy; odorless ...... | ...... | .... |
| date | 490.0 | ...... | ...... | 7.644 | .208 | .098 | .272 | 6.400 | " " ...... | ...... | .... |
| 19 | 413.4 | 142.4 | ...... | 7.640 | .212 | .067 | .192 | 5.360 | " " ...... | ...... | .... |
| ean . | 439.3 | 111.2 | ...... | 7.161 | .291 | .076 | .236 | 5.520 | | | |

## Table XXXII.—Cairo.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 641.4 | 445.7 | ...... | 7.778 | .194 | .072 | .430 | 6.320 | Muddy; odorless ...... | †70.28 | †.11 |
| 8 | 692.0 | 509.2 | ...... | 7.080 | .180 | .084 | .266 | 6.480 | " " ...... | 64.71 | .49 |
| 15 | 399.8 | ...... | ...... | 8.088 | .215 | .109 | .496 | 12.480 | " " ...... | 63.00 | .49 |
| ean . | 577.7 | 318.3 | ...... | 7.648 | .196 | .088 | .397 | 8.426 | | | |

*Observations—U. S. Signal Service. St. Louis.
†Observations—U. S. Signal Service, Cairo.

The test at Alton show the effect of mixture with the water o the Illinois. is evidently no increase in organic mat er, compar ng ame dates, but a very pe ble increase in chlorine and hardness. During the winter the water was generall bid, and characterized by an increase of free and albuminoid ammonia.

At East St. Louis we have a mixture of M ssissippi, Illinois and Missouri waters, and no great change from what is ound at Alton. The proportion of Mi water must be small.

The water sent from the river at St. Louis was too muddy for an accura e det ation of some points. The increased chlorides, undoubtedly due to the Missou tinguish this from that aken on the opposite bank. The improvement in the basin is quite apparent but does not go far enough. The tests at Chester an show that the waters of the three s ream have become more thoroughly mixe chlorides are higher than at Alton or East St. Louis, but lower than at St. Louis. is apparently no increase in organic matter.

## The Ohio River.

In Table XXXIII we have the results of a few tests of Ohio river water at Cair first th ee tests were made on the natural river water and the five following same water after filtration through a patented filter. The apparent increase of fi monia may be due to the alum used as a coagulant. The oxidation and albumin monia tests show a reduction in organic matter, but less marked than was antici

### Table XXXIII.—Ohio River, Cairo.

UNFILTERED.

| Date. 1888. | | Total Solids... | Suspended matter........ | Nitrogen in Nitrates...... | Chlorine....... | Hardness $CaCO_3$........ | Free Ammonia | Alb. Ammonia. | Oxygen consumed......... | Physical Conditio |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct. | 1 | 273.2 | 199.5 | trace | 3.894 | 66. | .038 | .270 | 6.880 | Muddy; yellowish; odor |
| " | 8 | 185.0 | 88.8 | 0.00 | 1.416 | 71. | .038 | .145 | 3.040 | Turbid; odorless ........ |
| " | 15 | 167.0 | 62.5 | 0.00 | 4.004 | ...... | .174 | .138 | 3.680 | ........................... |
| Mean.... | | 208.4 | 116.9 | 0.00 | 3.104 | 46. | .083 | .184 | 4.533 | |

FILTERED.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct. | 9 | 164.0 | 3.6 | 0.00 | 1.777 | 75. | .050 | .075 | 2.960 | Clear; odorless.......... |
| " | 15 | 110.8 | 8.2 | 0.00 | 4.368 | 95. | .073 | .082 | 2.960 | " " |
| Mean.... | | 137.4 | 5.9 | 0.00 | 3.069 | 85. | .061 | .078 | 2.965 | |

FILTERED AND AERATED.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct. | 1 | 202.8 | 2.5 | ...... | 2.236 | 80. | .109 | .098 | 1.280 | Clear; odorless.......... |
| " | 9 | 150.0 | 2.0 | 1.765 | 2.230 | 73. | .085 | .083 | 3.840 | " " |
| " | 15 | 111.0 | 3.6 | 0.00 | 4.004 | 83. | .095 | .086 | 2.520 | " " |
| Mean.... | | 154.6 | 2.7 | 0.00 | 2.823 | 78. | .096 | .088 | 2.546 | |

## Water from State Institutions.

Several samples from each of the state institutions have been examined, the results of which a e given below.

### KANKAKEE INSANE ASYLUM.

The water is taken from a filtering gallery, cut through sand rock for a distance of nearly one-fourth of a mile, parallel to the Kankakee river; also, in part from the river directly, as the filtered supply is not always sufficient. The analyses made are as follows:

Table XXXV.

| Date. 1888. | Total Solids... | Suspended matter...... | Nitrogen in Nitrates...... | Chlorine...... | Hardness $CaCO^3$...... | Free Ammonia | Alb. Ammonia. | Oxygen consumed...... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|
| Sept. 18 | 244.8 | 18.2 | ...... | 1.775 | 210. | .014 | .372 | 16.160 | Nearly clear; yellowish; odorless |
| " 25 | 231.0 | 11.0 | ...... | 1.770 | 216. | .057 | .296 | 5.760 | Clear and odorless............... |
| Oct. 2 | 251.2 | 17.0 | ...... | 1.649 | 230. | .046 | .280 | 5.840 | " " " |
| " 9 | 253.0 | 15.0 | ...... | 2.000 | 206. | .054 | .240 | 5.600 | Clear; earthy odor............... |
| " 25 | 300.4 | 15.0 | ...... | 3.150 | 254. | .016 | .150 | 5.040 | Nearly clear; odorless........... |
| M ... | 256.1 | 15.2 | ...... | 2.069 | 223. | .037 | .267 | 7.680 | |

### ANNA INSANE ASYLUM.

This institution is supplied with surface water which collects largely in sink holes and passes by subterranean channels to a large cavern or natural reservoir. This is called the "spring." From there it is pumped into settling basins, where a great deal of earthy matter is deposited, and then to filter beds where it is thoroughly cleared. It is pumped into the building from the beds. The second and third tests indicate a fairly good water.

Table XXXVI.

| Date. 1888. | Total Solids... | Suspended matter...... | Nitrogen in Nitrates...... | Chlorine...... | Hardness $CaCO^3$...... | Free Ammonia | Alb. Ammonia. | Oxygen consumed...... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|
| Oct. 13 | 160.6 | 4.2 | ...... | 6.02 | 120. | .396 | .122 | 2.40 | Clear and odorless............... |
| " 20 | 171.6 | 1.5 | ...... | 4.368 | 133. | .071 | .174 | 2.56 | " " " |
| " 27 | 199.2 | 1.5 | trace | 4.248 | 140. | .026 | .100 | 2.40 | " " " |
| Mean.... | 177.1 | 2.4 | ...... | *4.878 | 131. | .164 | .132 | 2.45 | |

### ELGIN INSANE ASYLUM.

The three samples analyzed were from a spring on the grounds. The water appears to be very good

TABLE XXXVII.

| Date. 1888. | | Total Solids... | Suspended matter....... | Nitrogen in Nitrates...... | Chlorine...... | Hardness $CaCO^3$....... | Free Ammonia | Alb. Ammonia. | Oxygen consumed....... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct. | 18 | 358.0 | 9.0 | trace | 2.912 | 296. | .026 | .069 | .640 | Clear and odorless........... |
| " | 22 | 342.8 | 4.6 | ...... | 4.586 | 316. | .012 | .026 | 1.04 | " " " |
| " | 29 | 353.4 | 1.2 | trace | 2.890 | 290. | .028 | .060 | 1.12 | " " " |
| Mean.... | | 351.4 | 4.9 | ...... | 3.462 | 300. | .022 | .051 | .933 | |

JACKSONVILLE INSANE ASYLUM.

The water used in this asylum is obtained from the town supply, described later. It is passed through a filter, which, to judge from the specimens examined, does not purify it as fully as is claimed. The large amount of free ammonia may come in part from the ammonia, alum used as a coagulant, but further tests are needed before pronouncing definitely upon the results of the filtration.

TABLE XXXVIII.

| Date. 1888. | | Total Solids... | Suspended Matter....... | Nitrogen in Nitrates...... | Chlorine...... | Hardness $CaCO^3$....... | Free Ammonia | Alb. Ammonia. | Oxygen consumed....... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct. | 15 | 193.0 | 2.0 | ...... | 4.368 | 140. | .258 | .190 | 4.080 | Clear; strong earthy odor...... |
| " | 26 | 207.4 | 3.2 | ...... | 2.478 | 156. | .270 | .404 | 5.060 | Clear; odorless.................. |
| " | 31 | 191.0 | 31.1 | ...... | 2.465 | 180. | .466 | .486 | 5.920 | Opalescent; odorless........... |
| Mean.... | | 197.1 | 12.1 | ...... | 3.103 | 158. | .331 | .360 | 5.020 | |

JACKSONVILLE DEAF AND DUMB ASYLUM.

The supply here is taken from the city and filtered. But two tests were made. These show less free ammonia, and about the same amount of albuminoid as is found in the asylum water.

TABLE XXXIX.

| Date. 1888. | | Total Solids... | Suspended matter....... | Nitrogen in Nitrates...... | Chlorine...... | Hardness $CaCO^3$....... | Free Ammonia | Alb. Ammonia. | Oxygen consumed....... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct. | 30 | 172.2 | 3.5 | ...... | 4.248 | 134. | .054 | .388 | 5.680 | Clear; odorless.................. |
| " | 30 | 240.6 | 51.5 | ...... | 2.832 | 160. | .022 | .380 | 5.920 | Slightly turbid; odorless........ |
| Mean.... | | 206.4 | 27.5 | ...... | 3.540 | 147. | .038 | .384 | 5.800 | |

LINCOLN ASYLUM FOR FEEBLE MINDED CHILDREN.

The supply here is taken from the mains of the waterworks company. The company's wells are connected with filtering galleries, constructed a few years ago. I made two analyses of this water in September, 1887. They gave closely agreeing results. The results obtained from the first test were in parts per million:

| | |
|---|---|
| Sodium chloride | 3.8 |
| Potassium chloride | 12.6 |
| Potassium sulphate | 17.6 |
| Calcium sulphate | 11.6 |
| Calcium carbonate | 125.3 |
| Magnesium carbonate | 81.2 |
| Ferric oxide and alumina | 11.3 |
| Silica | 12.2 |
| | |
| Free ammonia | .018 |
| Alb. ammonia | .052 |
| Oxygen consumed | .960 |

ıe water is supplied from a small stream and is evidently well filtered in the gal- . The recent tests do not indicate much change, except in the amount of oxygen ımed, as shown by the table below.

TABLE XL.

| e. ı. | Total Solids... | Suspended Matter........ | Nitrogen in Nitrates...... | Chlorine....... | Hardness $CaCO^3$........ | Free Ammonia | Alb. Ammonia. | Oxygen consumed........ | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|
| 15 | 336.8 | 15.3 | ...... | 5.460 | 290. | .005 | .061 | 1.60 | Clear; odorless.................... |
| 22 | 308.0 | 15.1 | ...... | 5.824 | 290. | .008 | .092 | 3.20 | Yellowish; odorless............... |
| 3 | 333.0 | 2.5 | ...... | 3.540 | 276. | .034 | .047 | 2.80 | Clear; odorless.................... |
| ın.. | 325.9 | 10.9 | ...... | 4.941 | 285. | .015 | .066 | 2.53 | |

PONTIAC REFORM SCHOOL.

ıis water supply is taken from a well, which is 24 feet deep sunk through strata ıdy loam and sand; 150 feet from the well there is an artificial pond, supplied by from an artesian well. This water is heavily charged with salt, which possibly ısts the source of supply of the shallow well, as the water here shows a large nt of chlorides. The privy vault is 400 feet from the well.

TABLE XLI.

| ·. | Total Solids... | Suspended matter....... | Nitrogen in Nitrates....... | Chlorine....... | Hardness $CaCO^3$... ... | Free Ammonia | Free Ammonia | Oxygen consumed....... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|
| 17 | 1609.4 | 16.0 | ...... | 480.48 | 536. | .421 | .116 | 1.84 | Nearly clear; odorless............ |
| 29 | 1582.0 | 7.1 | ...... | 495.60 | 504. | .048 | .081 | 2.32 | Clear; odorless.................... |
| 2 | 1829.8 | 8.9 | ...... | 584.10 | 528. | .294 | .038 | 2.16 | " " .................... |
| n.. | 1673.7 | 10.6 | ...... | 520.06 | 522. | .254 | .078 | 2.10 | |

CHESTER STATE PRISON.

e supply here is rain water. Two samples tested had been filtered, and two not; ɛered water is of good quality.

TABLE XLII.

| Date. 1888. | | Total Solids... | Suspended ma ter....... | Nitrogen in Nitrates ...... | Chlorine....... | Hardness $CaCO^3$....... | Free Ammonia | Alb. Ammonia | Oxygen consumed....... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct. | 15 | 122.0 | 15.1 | ...... | .354 | 62. | .088 | .352 | 10.800 | Clear. ....................................... |
| " | 22 | 95.8 | 3.4 | trace | .724 | 75. | .105 | .350 | 9.840 | Yellowish; organic odor.......... |
| Mean.. | | 108.9 | 9.2 | ...... | .539 | 68.5 | .096 | .351 | 10.320 | |

FILTERED.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct. | 22 | 66.2 | ...... | ...... | .603 | 42. | .008 | .042 | 1.920 | Clear; odorless.................... |
| " | 29 | 75.2 | 1.3 | ...... | .708 | 40. | .006 | .046 | 2.400 | " " .................... |
| Mean.. | | 70.7 | .65 | ...... | .655 | 41. | .007 | .044 | 2.160 | |

JOLIET STATE PRISON.

The supply of the Joliet Penitentiary is obtained from two artesian wells, one 553 feet deep and the other 1,948 feet deep. The flow from the former stopped during the autumn and at the present time the deep well furnishes all the water used. The three tests show marked variations in the quality of the water. Free ammonia is usually found in large quantity in artesian waters but the albuminoid in this well is very high and suggests the propriety of further investigation.

TABLE XLIII.

| Date. 1888. | | Total Solids... | Suspended matter....... | Nitrogen in Nitrates ...... | Chlorine....... | Hardness $CaCO^3$....... | Free Ammonia | Alb. Ammonia. | Oxygen consumed....... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct. | 13 | 794.6 | 2.00 | ...... | 233.64 | 220.0 | 14.160 | .420 | 1.600 | Clear and odorless................ |
| " | 20 | 810.4 | 2.30 | Tr'ce | 224.20 | 300.0 | .328 | .920 | 2.240 | " " ................ |
| " | 29 | 695.8 | 1.00 | ...... | 141.60 | 206.0 | 2.360 | .240 | 3.840 | " " ................ |
| Mean.. | | 766.9 | 1.76 | ...... | 199.80 | 242.0 | 5.616 | .526 | 2.560 | |

NORMAL, SOLDIERS' ORPHANS' HOME.

The water supply is furnished by a well on the grounds 105 feet deep, 60 feet of which is 7 feet in diameter and alled up with brick and timber. Below this is 45 feet of 7 inch iron pipe and a strainer at the bottom. The water is not filtered before use. It seems to be somewhat similar to that of Bloomington, referred to below. At the present time from 800 to 1,000 barrels per day is furnished.

TABLE XLIV.

| Date. 1888. | | Total Solids... | Suspended matter....... | Nitrogen in Nitrates ...... | Chlorine....... | Hardness $CaCO^3$....... | Free Ammonia | Alb. Ammonia. | Oxygen consumed....... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|---|
| Jan. | 14 | 456.5 | 9.0 | 1,650 | 3.240 | ...... | .885 | .133 | 2.320 | Clear; o orless.................... |
| " | 21 | 419.0 | 10.4 | 2,010 | 1,765 | ...... | 1.064 | .131 | 2.96 | " " .................... |
| " | 29 | 385.0 | 22.2 | 2,898 | 1.750 | ...... | 1.232 | .079 | 2.56 | " " .................... |
| Mean . | | 420.2 | 13.86 | 2,186 | 2.226 | ...... | 1.060 | .114 | 2.61 | |

## Town Supplies.

### JACKSONVILLE.

The usual supply is surface water, collected in a ravine. A dam across this forms a basin, out of which the mains a:e filled.

In dry weather, the "Davenport" well, so called, is used. This well is an abandoned coal shaft, 210 feet deep. Working it for coal was given up because of the great amount of water which collected.

An artesian well is also used in dry weather It is 2,400 feet deep and discharges 120,000 gallons of water daily.

The tests show that the surface water is far from satisfactory. The one analysis of the Davenport water indicates much organic matter in solution. The artesian water is very hard and heavily charged with salt.

Table XLV.

| Dat . 1888. | | Total Solids... | Suspended matter...... | Nitrogen in Nitrates ..... | Chlorine...... | Hardness $CaCO^3$....... | Free Ammonia | Alb. Ammonia. | Oxygen consume ...... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct. | 15 | 774.6 | 472.7 | ...... | 2.548 | 160. | .192 | .195 | 29.92 | Turbid; very strong earthy odor. |
| " | 25 | 292.2 | ...... | Tr'ce | 5.542 | 186. | .050 | .620 | 12.64 | Turbid; odorless.................. |
| " | 26 | 197.0 | 2.1 | " | 5.510 | 160. | .128 | .424 | 6.80 | Clear; " .................. |
| " | 30 | 275.0 | ...... | ...... | 3.894 | 184. | .072 | .480 | 14.560 | Turbid; " .................. |
| " | 31 | 210.0 | 9.4 | ...... | 2.832 | 160. | .045 | .482 | 7.360 | Slightly turbid; earthy odor..... |
| " | 29 | 2522.2 | 1.1 | ...... | 934.5 | 460. | 1.228 | .016 | 2.800 | Artesian well—Clear and odorless.............................. |
| " | " | 2591.2 | 1.5 | ...... | 1005.4 | 470. | 1.428 | .280 | 3.440 | |
| " | 30 | 1191.6 | 52.4 | ...... | 169.92 | 436. | 2.508 | .290 | 6.560 | Davenport well—Nearly clear; odorless.......................... |

### AURORA.

The water supply of Aurora is taken from the Fox river, and is drawn from an island in the river, 1.200 feet long and 200 feet wide. In the center of the island is a conduit or gallery 800 feet long, made by excavating to the rock 12 feet down and building up a wall of rubble stone on each side, covered on the top with hemlock joists set on edge and one-half inch apart, the joists are in turn covered with gravel and soil. The conduit thus formed has a section of 4 feet, and is connected by a pipe with the pumping works a mile north of the city. In the winter about 300,000 gallons daily is pumped, while in the summer the amount is increased to from 1,500,000 to 2,500,000 gallons, the tests are as follows:

Table XLVI.

| Date. 1888. | | Total Solids... | Suspended matter...... | Nitrogen in Nitrates ..... | Chlorine...... | Hardness $CaCO^3$....... | Free Ammonia | Alb. Ammonia. | Oxygen consumed...... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|---|
| Sept. | 21 | 288.0 | 2.6 | ...... | 2.124 | 260. | .068 | .208 | 3.760 | Clear and odorless................ |
| " | 28 | 296.6 | 2.6 | Tr'ce | 2.478 | 294. | .084 | .206 | 4.160 | " " ................ |
| Oct. | 5 | 299.4 | 2.5 | ...... | 2.365 | 282. | .048 | .196 | 4.000 | " " ................ |
| " | 13 | 326.0 | 5.8 | ...... | 2.832 | 308. | .064 | .148 | 4.000 | " " ................ |
| Mean.. | | 302.5 | 3.4 | ...... | 2.449 | 261. | .066 | .189 | 3.980 | |

### FREEPORT.

The supply is from eighteen artesian wells tubed to a depth of 44 feet. At the surface these pipes are connected with a 16-inch main. The water is hard, but otherwise good.

TABLE XLVII.

| Date. 1888. | Total Solids... | Suspended matter...... | Nitrogen in Nitrates...... | Chlorine...... | Hardness $CaCO^3$...... | Free Ammonia | Alb. Ammonia. | Oxygen consumed...... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|
| Sept. 25 | 456.0 | 1.0 | 5.540 | 12.506 | 454. | .032 | .086 | 1.360 | Clear and odorless................ |
| Oct. 2 | 470.6 | 1.8 | 9.324 | 14.160 | 434. | .038 | .049 | .720 | " " ................ |
| " 9 | 537.0 | 1.0 | 5.160 | 11.790 | 448. | .040 | .076 | 1.600 | " " ................ |
| " 16 | 448.4 | 3.2 | 5.040 | 13.104 | 405. | .013 | .031 | 7.776 | " " ................ |
| Mean.. | 475.5 | 1.7 | 6.266 | 12.890 | 435. | .031 | .060 | 2.866 | |

### ELGIN.

The Elgin water is taken from the Fox river, and is passed through filters. At the time the samples were collected these filters were not working well. The large amount of free ammonia in two of the samples tested came from the ammonia alum employed as a coagulant in the filters.

TABLE XLVIII.

| Date. 1888. | Total Solids... | Suspended matter...... | Nitrogen in Nitrates...... | Chlorine...... | Hardness $CaCO^3$...... | Free Ammonia | Alb. Ammonia. | Oxygen consumed...... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|
| Sept. 24 | 269. | 2.2 | ...... | 1.775 | 290. | .510 | .316 | 4.560 | Clear and odorless............ .... |
| Oct. 8 | 266. | 1.2 | trace | 5.372 | 282. | .053 | .296 | 4.800 | " " ................ |
| " 19 | 264.6 | 2.7 | ...... | 2.548 | 276. | .233 | .214 | 2.640 | " " ................ |
| Mean.. | 266.5 | 2.0 | ...... | 3.232 | 282. | .265 | .275 | 4.000 | |

### PEORIA.

A part of the water used in the city is taken from the Illinois river, and has already been described. A portion of the drinking water used is furnished by springs in the higher part of the city.

An experimental well known as the "city well" furnishes water which could not be used as it is badly contaminated and yellow. A series of analyses was made of the water from a well 33 feet deep, at the upper sugar works, and also from a driven well 70 feet, at the Monarch distillery. The direct indications of organic matter are not pronounced in either case, but the nitrates and chlorides of the well at the sugar works suggest strong contamination with oxidized sewage. At the distillery well the indications are much less pronounced. These wells are both near the river.

### Table XLIX.—"City Well," (not in use.)

| Date. 1888. | Total Solids... | Suspended matter...... | Nitrogen in Nitrates ...... | Chlorine...... | Hardness $CaCO^3$....... | Free Ammonia | Alb. Ammonia. | Oxygen consumed...... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|
| Aug. 7 | 796.2 | 7.5 | 8.075 | 79.175 | 544. | .179 | .120 | 1.120 | Clear; odorless.................... |
| " 22 | 713.5 | 19.5 | 1.134 | 60.767 | 500. | .242 | .290 | 4.720 | Slight opalescence; odorless..... |
| Sept. 20 | 670.8 | 24.4 | .756 | 81.066 | 374. | .144 | .198 | 4.800 | Yellow; turbid; odorless......... |
| " 27 | 664.6 | 41.2 | 3.780 | 70.920 | 400. | .454 | .152 | 4.000 | " " " ........ |
| Oct. 4 | 687.0 | 48.2 | trace | 81.774 | 414. | .346 | .136 | 2.720 | Yellow; tu bid; earthy odor..... |
| " 10 | 696.4 | 31.3 | 1.512 | 71.150 | 324. | .484 | .192 | 2.800 | Yellowish; odorless.............. |
| Mean . | 704.7 | 27.6 | 2.543 | 74.142 | 426. | .308 | .181 | 3.360 | |

### Well at Monarch Distillery.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| June 1 | 371.5 | 4.5 | 7.875 | 2.944 | 310.8 | .002 | .037 | .960 | Clear; odorless.................... |
| Aug. 21 | 373.0 | 4.5 | 7.560 | .587 | 306.0 | .144 | .188 | .416 | Clear; yellowish; odorless...... |
| Sept. 20 | 424.6 | 4.0 | 5.560 | 2.710 | 314.0 | .046 | .028 | 1.120 | Clear; odorless.................... |
| " 27 | 399.0 | 3.2 | 7.300 | 2.700 | 314.0 | .047 | .030 | .960 | " " .................... |
| Oct. 4 | 432.6 | 1.7 | 7.560 | 2.832 | 350.0 | .027 | .091 | .720 | " " .................... |
| " 10 | 416.0 | 4.1 | 6.426 | 2.340 | 320.0 | .047 | .059 | 1.920 | " " .................... |
| Mean . | 402.8 | 3.6 | 7.380 | 2.350 | 319.1 | .035 | .072 | 1.016 | |

### Well at Upper Sugar Works.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| June 1 | 761.4 | 2.5 | 11.970 | 61.950 | 480.0 | .012 | .014 | 1.44 | Clear; odorless.................... |
| Aug. 21 | 678.2 | 1.0 | 18.900 | 41.524 | 496.0 | .017 | .021 | 1.12 | Clear; colorless; odorless........ |
| Sept. 20 | 784.0 | 2.0 | 11.592 | 33.509 | 486.0 | .015 | .054 | 1.20 | Clear; odo less.................... |
| " 27 | 637.8 | 1.3 | 8.825 | 35.400 | 520.0 | .077 | .080 | 1.20 | " " .................... |
| Oct. 4 | 731.9 | 3.0 | 8.568 | 30.444 | 490.0 | .122 | .460 | 1.68 | " " .................... |
| " 10 | 680.0 | 6.5 | 4.788 | 36.820 | 496.0 | .389 | .088 | 1.92 | Clear; organic odor.............. |
| Mean . | 712.0 | 2.7 | 10.773 | 34,941 | 494.6 | .105 | .119 | 1.42 | |

## BEARDSTOWN.

The samples sent from this city were obtained from two artesian wells. They are heavily charged with salt, and when allowed to stand throw up a layer of oil.

### Table L.

| Date. 1888. | Total Solids... | Suspended matter....... | Nitrogen in Nitrates...... | Chlorine. ...... | Hardness $CaCO^3$........ | Free Ammonia | Alb. Ammonia. | Oxygen consumed....... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|
| July 9 (1) | 6480.3 | 10.0 | ..... | 3405.5 | 302.0 | 2.900 | .112 | 17.360 | Clear; oily odor................... |
| " 16 (1) | 6200.5 | 3.5 | ..... | 3143.5 | 296.0 | 3.782 | .326 | 18.320 | " " .................. |
| " 9 (4) | 11219.2 | 4.7 | ..... | 6230.4 | 548.0 | 3.836 | .088 | 10.560 | " " .................. |
| " 16 (4) | 10797.0 | 28.8 | ..... | 4956.0 | 480.0 | 5.696 | .128 | 13.920 | " " .................. |

### BELLEVILLE.

The supply is surface water collected by a creek, and from springs. The water accumulates in a storage reservoir and is filtered to the city mains. The appearance of the water is much improved by the filtration, but a certain amount of organic matter is still found in it.

TABLE LI.

| Date. 1888. | | Total Solids... | Suspended matter....... | Nitrogen in Nitrates...... | Chlorine....... | Hardness $CaCO^3$........ | Free Ammonia | Alb. Ammonia. | Oxygen consumed....... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|---|
| Sept | 18 | 162.0 | 21.3 | ...... | 2.124 | 130. | .184 | .560 | 7.200 | Reservoir, slightly turbid; yellowish .......................... |
| " | 24 | 161.4 | 22.7 | ...... | 2.003 | 118. | .065 | .570 | 4.560 | |
| Oct. | 10 | 136.0 | 19.4 | ...... | 4.248 | 80. | .070 | .516 | 7.600 | New reservoir; clear ............. |
| Sept. | 18 | 149.4 | 5.8 | ...... | 1.775 | 125. | .160 | .354 | 5.600 | Stand pipe filtered ................ |
| " | 18 | 144.6 | 3.1 | trace | 1.770 | 124. | .042 | .287 | 5.600 | Stand pipe filtered, aerated...... |
| " | 24 | 155.2 | 4.4 | trace | 2.360 | 128. | .058 | .370 | 5.040 | Hydrant, clear; organic odor ... |
| " | 24 | 1234.0 | 8.1 | 15.620 | 90.386 | 892. | .028 | .116 | 2.240 | Market place well, clear.......... |
| " | 18 | 1902.4 | 4.5 | 35.280 | 226.560 | 1130. | .064 | .050 | 2.640 | Wells in different parts of the city.............................. |
| Oct. | 10 | 2029.0 | 4.6 | 11.718 | 207.090 | ...... | .144 | .280 | 3.600 | |
| " | 10 | 1672.6 | 5.1 | 65.520 | 161.430 | 852. | .048 | .050 | 7.080 | |
| Sept. | 18 | 1575.0 | 8.2 | 60.480 | 141.600 | 980. | .010 | .088 | 2.320 | Spring water ........................ |

### GALENA.

The water is obtained from an artesian well 1507 feet deep, having a diameter of 8 inches, the flow is 2,000 gallons per minute. These tests show a satisfactory degree of purity.

TABLE LII.

| Date. 1888. | | Total Solids... | Suspended matter....... | Nitrogen in Nitrates...... | Chlorine....... | Hardness $CaCO^3$........ | Free Ammonia | Alb. Ammonia. | Oxygen consumed....... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct. | 11 | 271.6 | 2.8 | ...... | .567 | 270. | .169 | .062 | 2.320 | Clear; odorless..................... |
| " | 18 | 295.0 | 2.6 | ...... | .708 | 264. | .105 | .059 | 3.200 | " " ..................... |
| " | 27 | 285.8 | 3.6 | ...... | .560 | 270. | .022 | .020 | .800 | " " ..................... |
| Nov. | 10 | 292.0 | 1.7 | ...... | .587 | ...... | .006 | .105 | 2.240 | " " ..................... |
| Mean . | | 286.1 | 2.6 | ...... | .605 | 201. | .075 | .061 | 2.140 | |

### DANVILLE.

The supply is from a small river, and is not filtered. It has the same character as waters found in similar streams in all parts of the state.

TABLE LIII.

| Date. 1888. | | Total Solids... | Suspended matter....... | Nitrogen in Nitrates...... | Chlorine....... | Hardness $CaCO^3$........ | Free Ammonia | Alb. Ammonia. | Oxygen consumed....... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct. | 18 | 356.6 | 15.5 | ...... | 3.276 | 324. | .044 | .172 | 3.040 | Nearly clear; odorless............ |
| " | 25 | 299.2 | 6.6 | ...... | 2.834 | 290. | .010 | .068 | 2.960 | " " " ............ |
| Nov. | 5 | 297.6 | ...... | ...... | 2.900 | 240. | .086 | .198 | 4.240 | " " " ............ |
| " | 5 | 395.0 | ...... | ...... | 2.830 | 304. | .192 | .198 | 3.480 | " " " ............ |
| Mean . | | 337.1 | 11.0 | ...... | 2.960 | 289. | .060 | .159 | 3.430 | |

## PEKIN.

The water is furnished by driven wells sunk to a depth of 75 feet, through a soil consisting chiefly of sand and gravel. The tests show a very satisfactory degree of purity.

TABLE LIV.

| Date. 1888. | Total Solids... | Suspended matter....... | Nitrogen in Nitrates...... | Chlorine...... | Hardness $CaCO^3$....... | Free Ammonia | Alb. Ammonia. | Oxygen consumed...... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|
| May 21 | 335.6 | 1.0 | 4.536 | 2.230 | 252.0 | .004 | .054 | .32 | Odorless; colorless................ |
| " 28 | 328.3 | 3.2 | 4.914 | 3.186 | 283.2 | .020 | .026 | .20 | " " ................ |
| June 6 | 328.3 | 2.5 | 5.229 | 3.433 | 290.0 | .008 | .022 | .72 | " " ................ |
| " 11 | 375.0 | 19.5 | .660 | 2.570 | 286.0 | .004 | .036 | 1.12 | Deposits a little iron on standing |
| Mean. | 341.8 | 6.5 | 3.834 | 2.854 | 277.8 | .009 | .034 | .59 | |

## MORRISON.

The supply is from a large well, and is shown by the tests to be of good quality. The well was sunk in 1881 around a large spring flowing out from a bluff on one side of Rock Creek bottom, a short distance from the city. The inside diameter of the finished well is 36 feet. It was sunk to the rock 12 feet below the surface, and three feet of this rock was afterwards excavated. In order to prevent overflow and contamination by the spring freshets, the wall was built up about 20 feet higher and the bluff graded down around it. The water stands 15 to 16 feet in depth and is always fresh and clear. Two overflow pipes, 2 and 4 inches in diameter carry off water near y all the time.

The supply for the city, estimated at 800 gallons per minute, is pumped to a large wooden tank or reservoir and there distributed by mains.

TABLE LV.

| Date. 1888. | Total Solids... | Suspended matter....... | Nitr gen in Nitrates...... | Chlorine....... | Hardness $CaCO^3$....... | Free Ammonia | Alb. Ammonia. | Oxygen consumed...... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|
| Sept. 14 | 397.4 | 4.1 | 10.690 | 9.416 | 360. | .008 | .022 | .400 | Clear; odorless.................... |
| " 24 | 379.4 | 3.5 | 3.276 | 4.718 | 340. | .010 | .036 | 1.040 | " " .................... |
| Oct. 1 | 379.6 | 3.3 | 5.040 | 8.496 | 346. | .013 | .019 | 1.520 | " " .................... |
| " 8 | 405.4 | 1.2 | 6.680 | 7.313 | 348. | .008 | .055 | 1.440 | " " .................... |
| Mean. | 390.4 | 3.0 | 6.421 | 7.485 | 348.5 | .009 | .033 | 1.100 | |

## JOLIET.

The water furnished the city is obtained at the present time wholly from artesian wells. There are three of these wells having a depth of 1,200 feet, and the amount flowing is considered sufficient for present needs.

Three of the tests given below show good results, in the one of July 26th the result is not as favorable owing to what must have been an accidental contamination of the water.

TABLE LVI

| Date. | Total Solids... | Suspended mat'er....... | Nitrogen in Ni ates...... | Ch orine....... | Hardness $CaCO^3$....... | Free Ammonia | Alb. Ammonia. | Oxygen consumed....... | Physical Conditi ns. |
|---|---|---|---|---|---|---|---|---|---|
| July 12 | 491.4 | 12.5 | .630 | 8.850 | 340.0 | .038 | .105 | 2.880 | Clear ................................ |
| " 19 | 429.5 | 4.5 | .442 | 9.437 | 326.0 | .044 | .053 | 2.640 | " ................................ |
| " 26 | 474.2 | 28.6 | .316 | 8.238 | 316.0 | .010 | .360 | 12.080 | Floating matter; probably accide tal ........................... |
| Aug. 2 | 438.4 | 5.2 | .550 | 6.726 | 314.0 | .014 | .082 | 1.600 | Clear and odorless................ |
| *Mean. | 453.1 | 7.4 | .541 | 8.337 | 326.6 | .032 | .080 | 2.373 | |

*Not including July 26.

GALESBURG.

The city supply is taken from a large well. The tests show a large amount of free ammonia with small albuminoid and low oxygen consumption and chlorides.

I have made other full analyses of this water, and find that it deposits iron on standing in the air. After such deposition it is almost entirely free from organic matter and is, apparently, quite suitable for use. But it is claimed that in pumping from this well others in the neighborhood are immediately drawn dry. As the soil is evidently porous, consisting of gravel and loam I am informed, and as sources of contamination are not far removed, it may be necessary to carry out fuller and prolonged tests to determine the nature of the water.

The following is a full analysis of the water, in parts per million.

| | |
|---|---|
| Silica ........................................................ | 19.3 |
| Ferrous carbonate and alumina................................ | 65.0 |
| Calcium sulphate.............................................. | 5.7 |
| Calcium carbonate............................................ | 166.2 |
| Magnesium carbonate........................................ | 86.8 |
| Sodium carbonate............................................. | 25.8 |
| Potassium carbonate.......................................... | 7.4 |
| Sodium chloride .............................................. | 2.1 |
| Total solids..................................................... | 378.3 |

The recent special tests gave results as follows:

TABLE LVII.

| Date. 1888. | Total Solids... | Suspended matter....... | Nitrogen in Nitrates...... | Chlorine....... | Hardne s $CaCO^3$....... | Free Ammonia | Alb. Ammonia. | Oxygen consumed....... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|
| Sept. 19 | 413.2 | 14.7 | ...... | 1.180 | 350. | .848 | .150 | 2.800 | Nearly clear; odorless............ |
| " 28 | 396.4 | 21.0 | ...... | 1.180 | 368. | 1.004 | .086 | 2.000 | Iron deposits on standing; odorless..................................... |
| Oct. 6 | 396.4 | 8.0 | ...... | 1.181 | 384. | .890 | .092 | 2.400 | Clear; odorless.................... |
| " 13 | 391.4 | 1.8 | ...... | 1.198 | 380. | 1.000 | .123 | 2.400 | " " .................... |
| Mean . | 399.3 | 11.3 | ...... | 1.184 | 370. | .935 | .112 | 2.400 | |

### BLOOMINGTON.

Some years ago a company attempted to bore for coal at this place, but at a depth of 25 feet encountered a bed of coarse gravel through which the water came in in such quantities that the work had to be abandoned.

In 1874 the city sunk a well 40 feet in diameter and 28 feet deep at this point and obtained a good supply. This was increased in 1886 by sinking 7 eight-inch pipes around the outside of the well to a depth of 62 feet, and 3 similar pipes from the bottom of the well. The water rises and flows into the well from the last, while the seven are connected in such a manner that they can be used alone or in connection with the water of the well proper.

The citizens of Bloomington speak in the highest terms of the excellence of the water.

TABLE LVIII.

| Date. 1888. | Total Solids... | Suspended matter ........ | Nitrogen in Nitrates....... | Chlorine........ | Hardness $CaCo^3$........ | Free Ammoni. | Alb. Ammoni. | Oxygen consumed........ | Phy ical Conditions, |
|---|---|---|---|---|---|---|---|---|---|
| Sept. 17 | 643.0 | 2.8 | ...... | 5.310 | 582. | .922 | .074 | 1.280 | Clear; odorless.................... |
| " 24 | 562.8 | 9.2 | ...... | 3.894 | 452. | .952 | .137 | 1.920 | " " .................... |
| Oct. 1 | 593.8 | 1.2 | ...... | 3.894 | 460. | .950 | .077 | 2.720 | " " .................... |
| " 8 | 615.0 | 1.1 | ...... | 4.000 | 464. | .908 | .042 | 1.360 | " " .................... |
| Mean. | 603.6 | 3.5 | ...... | 4.249 | 489. | .933 | .082 | 1.820 | |

### SPRINGFIELD.

The Springfield waters examined were obtained from several sources. In February March and April a number of cases of typhoid fever occurred at Concordia College, and as the disease was becoming epidemic, the college was closed on April 23, 1888.

Eight of the students fell sick upon reaching their homes, of whom four died. There was a total of forty cases and twelve deaths. The well water was suspected and its use forbidden. and directions given that the institution should be throughly cleaned and purified. Upon opening of the college in September last the water of the well was, however, again used. No doubt in consequence of this and other causes, another outbreak occurred in February, 1889. twenty-three students falling ill with fever. The attendance falling off from 174 to 53 students. Another analysis of the water was made in February. The four samples sent from the so-called new well—one much used for drinking purposes—show, by analysis, a large amount of dissolved solid matter, with abundance of nitrates and chlorides. The last three ammonia and oxidation tests do not indicate an excessive amount of organic matter. It is probable that this has been mostly decomposed by the soil.

Water from three other wells in the immediate vicinity was examined. These are marked "old well", "well in pasture," and "well in professor's yard," and the tests here indicate a lower amount of solids, nitrates and chlorides. The free ammonia in the last two is high. It is interesting to note the change in the water of the "new well" between June 1 and June 15. We have a marked decrease in oxidation and in albuminoid ammonia, with a corresponding increase in nitrates. The mineral matter taken up from the soil is also increased. I am inclined to believe that the nitrates in the other wells are in excess of what should be found in ordinary wells of that locality.

The other waters tested were from the Sangamon river; from the hydrant in the office of the State Board of Health, before the water was pumped from the new well; and two samples from the well before the water was pumped from it, and the last from a hydrant at Concordia College, from the public supply drawn through the filtering galgallery. The filtering gallery is about a thousand feet in length, running back from the

Sangamon river toward a bluff. It is constructed at a depth of 20 to 25 feet below the surface, and in sand and gravel. The water is not furnished by the river, but from below the bluff. Occasionally it is necessary to pump a little directly from the river, as the daily average of 2,600,000 gallons cannot be furnished by the gallery itself. The "new well" at the pump house, from which some samples were taken, is connected with the gallery. The analyses show the improved character of this water as compared with the water heretofore directly obtained from the Sangamon river, and will, no doubt, show more improvement when the gallery furnishes all the water.

TABLE LIX.

CONCORDIA COLLEGE—New well.

| Date. 1888. | Total Solids... | Suspended matter...... | Nitrogen in Nitrates...... | Chlorine...... | Hardness $CaCO^3$...... | Free Ammonia | Alb. Ammonia. | Oxygen consumed...... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|
| 1888. June 1 | 1596.4 | 6.5 | 9.450 | 102.66 | 102.00 | .018 | .186 | 15.840 | Clear; odorless.................... |
| " 15 | 1888.0 | trace | 22.680 | 111.156 | 132.00 | .004 | .092 | 4.840 | " " .................... |
| Sept. 4 | 1876.0 | 4.8 | 22.050 | 101.123 | 136.00 | .008 | .082 | 3.600 | " " .................... |
| 1889. Feb. 22 | 1761.0 | trace | 19.530 | 145.140 | ...... | .045 | .072 | 2.400 | " " .................... |
| Mean.. | 1780.3 | 2.8 | 18.427 | 115.019 | 123.33 | .019 | .108 | 6.670 | |

WELL IN PROFESSOR'S YARD.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1888. Sept. 4 | 555.4 | 3.0 | 15.435 | 22.181 | .384 | .142 | .104 | 2.160 | Clear; odorless.................... |

WELL IN PASTURE.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sept. 4 | 629.4 | 14.3 | 18.900 | 21.240 | .440 | .548 | .161 | 2.720 | Clear; odorless.................... |

OLD WELL—NOT USED.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1888. June 15 | 698.4 | trace | 15.120 | 15.222 | .665 | .006 | .028 | 1.440 | Clear; odorless.................... |
| Sept. 4 | 671.5 | 22.5 | 13.860 | 21.473 | .568 | .002 | .055 | 1.120 | Opalescent......................... |
| Mean.. | 684.9 | 11.2 | 14.490 | 18.347 | .616 | .004 | .041 | 1.280 | |

HYDRANT—STATE BOARD OF HEALTH OFFICE.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1888. Aug. 25 | 252.5 | 14.5 | trace | 2.948 | .178 | .010 | .358 | 5.760 | Nearly clear; earthy odor........ |
| Sept. 5 | 288.7 | 35.2 | trace | 4.127 | .230 | .012 | .218 | 4.240 | Slight turbidity; yellowish; odorless................................ |
| Oct. 10 | 305.8 | 29.2 | trace | 6.726 | .248 | .022 | .186 | 3.283 | Colorless; odorless ............... |
| Mean.. | 282.3 | 26.3 | ...... | 4.600 | .218 | .014 | .254 | 4.427 | |

HYDRANT—ST. NICHOLAS HOTEL, DECATUR.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sept. 12 | 364.3 | 5.000 | ...... | 6.018 | 320 | .056 | .194 | 3.040 | Clear; bad odor.................... |

### Sangamon River.

| Date. 1888. | Total Solids... | Suspended matter ........ | Nitrogen in Nitrates...... | Chlorine....... | Hardness $CaCo^3$.... .... | Free Ammonia | Alb. Ammonia. | Oxygen consumed ........ | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|
| 1888. Oct. 12 | 295.8 | 11.8 | trace | 7.080 | 250 | .113 | .208 | 3.360 | Nearly clear; slight earthy odor. |

### New Well, Pump House.

| Date. | Total Solids | Suspended matter | Nitrogen in Nitrates | Chlorine | Hardness $CaCo^3$ | Free Ammonia | Alb. Ammonia. | Oxygen consumed | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|
| Sept. 13 | 377.4 | 24.8 | trace | 2.584 | 310 | .454 | .076 | 1.280 | Yellow; turbid; odorless.......... |
| Oct. 11 | 349.0 | 22.1 | trace | 5.310 | 280 | .363 | .093 | 2.320 | Yellow; turbid; organic odor.... |
| Mean.. | 363.2 | 23.4 | ...... | 3.947 | 295 | .408 | .084 | 1.800 | |

### Concordia College—Hydrant.

| Date. | Total Solids | Suspended matter | Nitrogen in Nitrates | Chlorine | Hardness $CaCo^3$ | Free Ammonia | Alb. Ammonia. | Oxygen consumed | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|
| 1889. Feb. 22 | 328.0 | trace | .00 | 4.956 | ...... | .219 | .095 | 3.600 | Clear; odorless.................... |

### Decatur.

A large number of analyses were made of waters from different public school wells and from several others in the city. These wells have generally a depth of 40 to 70 feet and are sunk first through 14 feet of yellow clay and then through a stratum of blue clay of variable thickness to a gravel bed.

These wells present several interesting features for study. It will be seen by the tests below that the waters of most of them are pretty hard and contain considerable amounts of chlorine and nitrates. The oxidation and ammonia tests do not show mu h organic matter actually existing. Local authorities suggest that these gravel beds, into which the wells are sunk, are connected with each other as wells have been drawn dry by pumping from others.

The large chlorine and nitrates suggest contamination with oxidized products of animal origin and if the wells are in communication, there may be found in this a source of future danger.

The Lincoln Square well is of different nature. Its water appears good.

The hydrant water is from the Sangamon river, and contains the usual constituents.

### Table LX.

### Wood Street School.

| Date. 1888. | Total Solids... | Suspended matter ...... | Nitrogen in Nitrates ..... | Chlorine....... | Hardness $CaCO^3$....... | Free Ammonia | Alb. Ammonia. | Oxygen consumed ...... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|
| Aug. 29 | 609. | trace | 11.970 | 21.800 | 448. | .002 | .016 | .880 | Clear; odorless.................... |
| Sept. 5 | 619. | " | 13.860 | 24.782 | 510. | .008 | .050 | 1.600 | " " .................... |
| " 12 | 673.2 | " | 6.048 | 21.594 | 490. | .013 | .050 | 1.120 | " " .................... |
| Mean.. | 633.76 | ...... | 10.626 | 22.725 | 482.6 | .0076 | .0386 | 1.200 | |

†The following is the mean of eight analyses of water, July-September, at Chandlerville (Sangamon river); Total solids, 317.8; suspended water, 70.7; nitrogen in nifrates, 755; chlorine, 3.609; hardness, ca $CO^3$,212; free ammonia, .058; alb. ammonia, .285; oxygen consumed, 5.480.

### Church Street School.

| Date. 1888. | Total Solids... | Suspended matter........ | Nitrogen in Nitrates...... | Chlorine...... | Hardness $CaCo^3$....... | Free Ammonia | Alb. Ammonia | Oxygen consumed....... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|
| Aug. 29 | 879.7 | trace | 13.860 | 53.210 | 580. | .003 | .054 | 3.680 | Clear; odorless.................... |
| Sept. 5 | 879.3 | " | 10.395 | 50.268 | 616. | .002 | .061 | 4.650 | " " .................... |
| " 12 | 896.4 | " | 10.132 | 53.100 | 620. | .002 | .070 | 2.400 | " " .................... |
| Mean.. | 885.1 | ...... | 11.462 | 52.192 | 605.3 | .0023 | .0616 | 3.576 | |

### Chambers' Lot.

| Date. 1888. | Total Solids... | Suspended matter........ | Nitrogen in Nitrates...... | Chlorine...... | Hardness $CaCo^3$....... | Free Ammonia | Alb. Ammonia | Oxygen consumed....... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|
| Aug. 29 | 986.2 | trace | 25.200 | 96.393 | 644. | .004 | .058 | 4.000 | Clear; odorless.................... |
| Sept. 5 | 988.2 | " | 27.090 | 63.120 | 690. | .178 | .124 | 8.000 | " " .................... |
| " 12 | 1026.0 | " | 25.704 | 85.668 | 700. | .014 | .084 | 1.600 | " " .................... |
| Mean.. | 1000.1 | ...... | 25.998 | 81.727 | 678. | .0653 | .088 | 4.533 | |

### Jackson Street School—North Well.

| Date. 1888. | Total Solids... | Suspended matter........ | Nitrogen in Nitrates...... | Chlorine...... | Hardness $CaCo^3$....... | Free Ammonia | Alb. Ammonia | Oxygen consumed....... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|
| Aug. 29 | 746.8 | trace | 26.480 | 33.120 | 548. | .008 | .070 | 1.920 | Clear; odorless.................... |
| Sept. 5 | 779.7 | " | 24.570 | 29.498 | 536. | .008 | .104 | 2.080 | " " .................... |
| " 12 | 774.0 | " | 23.940 | 29.558 | 500. | .024 | .076 | 2.240 | " " .................... |
| Mean.. | 766.8 | ...... | 24.996 | 30.725 | 528. | .013 | .083 | 2.080 | |

### Jackson Street School—South Well.

| Date. 1888. | Total Solids... | Suspended matter........ | Nitrogen in Nitrates...... | Chlorine...... | Hardness $CaCo^3$....... | Free Ammonia | Alb. Ammonia | Oxygen consumed....... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|
| Aug. 29 | 668.8 | trace | 17.010 | 26.311 | 544.0 | .002 | .042 | 2.000 | Clear; odorless.................... |
| Sept. 5 | 648.5 | " | 15.750 | 26.196 | 500. | .002 | .085 | 2.720 | " " .................... |
| " 12 | 682.4 | " | 13.608 | 26.550 | 544. | .006 | .098 | 2.080 | " " .................... |
| Mean.. | 666.5 | ...... | 15.456 | 26.352 | 529.3 | .0033 | .075 | 2.266 | |

### Jasper Street School.

| Date. 1888. | Total Solids... | Suspended matter........ | Nitrogen in Nitrates...... | Chlorine...... | Hardness $CaCo^3$....... | Free Ammonia | Alb. Ammonia | Oxygen consumed....... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|
| Aug. 29 | 780.5 | trace | 19.530 | 28.319 | 568. | .002 | .014 | 2.240 | Clear; odorless.................... |
| Sept. 5 | 733.4 | " | 18.585 | 22.418 | 600. | .002 | .068 | 2.240 | " " .................... |
| " 12 | 744.4 | " | 13.104 | 25.234 | 580. | .007 | .058 | 1.520 | " " .................... |
| Mean.... | 752.7 | ...... | 17.073 | 25.327 | 582. | .0036 | .0466 | 2.000 | |

### Sangamon Street School—East Well.

| Date. 1888. | Total Solids... | Suspended matter........ | Nitrogen in Nitrates...... | Chlorine...... | Hardness $CaCo^3$....... | Free Ammonia | Alb. Ammonia | Oxygen consumed....... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|
| Aug. 29 | 1661.4 | trace | 23.310 | 170.512 | 1040. | .012 | .058 | 2.960 | Clear; odorless.................... |
| Sept. 5 | 1616.7 | " | 23.310 | 141.600 | 980. | .002 | .095 | 2.880 | " " .................... |
| " 12 | 1406.4 | " | 35.280 | 109.470 | 890. | .002 | .092 | 2.960 | " " .................... |
| Mean.. | 1561.5 | ...... | 27.300 | 140.527 | 970. | .0053 | .0816 | 2.933 | |

SANGAMON STREET SCHOOL—WEST WELL.

| Date. 1888. | Total solids... | Suspended matter....... | Nitrogen in Nitrates...... | Chlorine......... | Hardness $CaCo^3$........ | Free Ammonia | Alb. Ammonia | Oxygen consumed...... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|
| Aug. 29 | 1589.5 | trace | 17.640 | 207.670 | 920. | .004 | .056 | 3.360 | Clear; odorless.................... |
| Sept. 5 | 1605.7 | " | 18.900 | 135.698 | 950. | .002 | .075 | 1.920 | " " .................... |
| " 12 | 1604. | " | 30.744 | 197.530 | 990. | .010 | .108 | 2.800 | " " .................... |
| Mean.. | 1599.7 | ...... | 22.428 | 180.299 | 953. | .0053 | .0796 | 2.693 | |

MARIETTA STREET SCHOOL.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Aug. 29 | 1106.0 | trace | 34.650 | 40.360 | 740. | .014 | .030 | 1.040 | Clear; odorless.................... |
| Sept. 5 | 1028. | " | 35.280 | 23.015 | 750. | .002 | .032 | 2.000 | " " .................... |
| " 12 | 892. | " | 28.224 | 29.736 | 610. | .046 | .056 | 1.125 | " " .................... |
| Mean.. | 1008.6 | ...... | 32.718 | 31.037 | 700. | .0206 | .0393 | 1.388 | |

BREWER'S WELL—28 feet deep.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sept. 12 | 899. | trace | 11.592 | 79.650 | 624. | .010 | .038 | 1.040 | Clear; odorless.................... |

LINCOLN SQUARE WELL—108 feet deep.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sept. 12 | 420.8 | trace | ...... | 9.204 | 380. | .474 | .076 | 4.280 | Clear; odorless.................... |

ST. NICHOLAS HOTEL HYDRANT.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sept. 12 | 364.3 | 5.000 | ...... | 6.018 | 320. | .056 | .194 | 3.040 | Clear; odorless.................... |

HOWELL'S WELL—30 feet deep.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sept. 12 | 642.0 | 4.2 | 2.270 | 82.128 | 456. | .154 | .076 | 1.280 | Clear; odorless.................... |

SUNDRY ANALYSES.

In the following table analyses are given of waters from various towns and cities, of which, in most cases, but a single sample was received.

TABLE LXI.

| Date. 1888. | Total Solids... | Suspended matter...... | Nitrogen in Nitrates...... | Chlorine...... | Hardness $CaCO^3$...... | Free Ammonia | Alb. Ammonia | Oxygen consumed...... | Physical Conditions. |
|---|---|---|---|---|---|---|---|---|---|
| Marseilles, Aug. 31, spring .............. | 476.6 | 53.3 | 5.796 | 14.762 | 348. | .087 | .172 | 3.200 | Opalescent; peaty odor. |
| Monticello well Sept. 14 .................... | 314.0 | 11.5 | trace | 3.186 | 248. | .006 | .160 | 4.160 | Clear; odorless .......... |
| Ottawa well, Sept. 11. | 1469.6 | 10.1 | 30.24 | 114.28 | 1320. | .032 | .260 | 4.000 | " " .......... |
| Ottawa well, Oct. 1... | 581.0 | 30.0 | trace | 124.90 | 426. | .652 | .050 | 1.360 | " " .......... |
| Galesburg, Sept. 19, Dr. Foote's spring. | 442.4 | 11.2 | .00 | 3.77 | 336. | 1.804 | .128 | 2.400 | Nearly clear; odorless.. |
| Bunker Hill, Oct. 30, spring................ | 704.8 | 3.3 | .00 | 4.956 | 484. | .138 | .026 | 1.040 | Clear; odorless.......... |
| Cairo, driven well, Oct. 2 ............... | 662.2 | 65.5 | .00 | 3.640 | 558. | 1.084 | .102 | 4.800 | Yellow; turbid; odorless |
| Cairo well, Oct. 15 .. | 658.8 | 15.5 | .00 | 3.494 | 520. | 1.086 | .090 | 4.240 | Yellow; t'bid; earthy od'r |
| Elkville, well, Sept, 24 | 548.4 | 20.5 | .00 | 1.295 | 318. | .060 | .075 | 2.720 | Nearly clear; odorless.. |
| Elkville well, Nov. 3. | 554.4 | 3.8 | .00 | 1.180 | 280. | .013 | .156 | 2.600 | Clear; odorless.......... |
| Elkhart, well, Nov. 10 | 598.0 | 6.6 | 22.76 | 3.894 | 400. | .060 | .102 | 2.24 | " " .......... |
| Elkhart, well, Nov. 10 | 1030.8 | 16.6 | .00 | 27.612 | 684. | 1.250 | .224 | 6.24 | Slightly turbid; strong odor of sulphuretted hydrogen............... |
| Elgin, asylum, artesian well, Oct. 11... | 312.8 | 2.0 | .00 | 14.160 | 264. | .201 | .092 | 16.88 | Clear; organic odor..... |
| LaSalle, east spring, June 25. ............ | 342.6 | .... | 1.14 | 2.650 | 316. | .114 | .038 | .920 | Clear; odorless.......... |
| LaSalle, west spring, June 25. ............ | 353.0 | .... | .63 | 1.440 | 328. | ...... | .... | 3.50 | " " .......... |

The spring at Marseilles is situated in low ground between the canal and Illinois river, and not removed from danger of contamination by dwellings near.

The two well waters from Ottawa were sent because there existed good grounds for believing them contaminated by house drainage. The high nitrates and chlorides with albuminoid ammonia and oxygen consumption certainly confirm this suspicion regarding the first.

In the second case the free ammonia and chlorine are very suspicious.

The waters from the driven well at Cairo were yellow when received, and deposited iron compounds with organic matter on standing. The well is 56 feet deep.

The two samples from LaSalle came from large springs east of the city from which the household supply is now pumped. These springs are situated in the valley between the Illinois river and the canal, and are walled up and covered.

The test of the east spring shows a satisfactory freedom from organic matter. The amount of water received from the other spring was too small for complete tests.

# THE ILLINOIS RIVER BASIN

IN ITS

# RELATIONS TO SANITARY ENGINEERING,

By L. E. COOLEY, C. E.

## PHYSICAL CONDITIONS.

To treat the hydrography of a river basin in a broad way, it is necessary to understand its geology,—the manner and method in which nature has disposed the rocks and fashioned the topography. As we appreciate the surface configuration, know the character of the superficial deposits, comprehend the statigraphical arrangement of the underlying rock and its permeable or impermeable character,—as we understand the forces which have wrought all this,—we see why river basins, valleys and stream beds are fashioned as we find them; how watersheds, under similar climatic conditions, differ in the volume and character of the floods turned into the streams, and how the dry-weather flow varies in volume and persistence. As these things are understood, we may reach conclusions upon the ultimate effect of conditions wrought by inhabitation upon the flow of the streams draining the several watersheds. This is a matter of great economic and sanitary importance.

It is not proposed to present this matter fully at this time, but briefly such a resumé as will present an epitome of the conditions prevailing in the watershed of the Illinois river above the Copperas Creek dam.

If we take a general view of the statigraphical arrangement of the underlying rocks of the State, the most pronounced feature is the anticlinial axis crossing the Illinois valley between Utica and La Salle,—perhaps the remnant of a mountain chain early denuded in geologic time,—extending in a general direction N. N. W. and S. S. E. Here are found the oldest rocks in the State, and the lowest horizon in the geological series, the Calciferous group of the Lower Silurian period.

This group outcrops upon the Rock river, in Ogle and Lee counties, and at the Falls of the Ohio, at Louisville. The lower magnesian limestone carries the water lime quarried at Utica and at Louisville, and above it lies the St. Peter's sandstone, extending along the Illinois from Utica to a point above Ottawa, from which the glass sand is derived.

In a general way, the rocks to the eastward of this axis succeed in regular series, The Trenton limestones lies to the north of the Illinois valley, then the Cincinnati group, (limestone with shaly partings,) crosses the Illinois valley in a belt some eight miles wide above Morris, and in which the bed of the lower Kankakee is situated. Both of these groups belong to the Lower Silurian.

Still above these in the series comes the Niagara limestone of the Upper Silurian, developed over a large extent of country in the northeast portion of the State, toward Lake Michigan. This rock underlies Chicago, extends down the Desplaines river to Channahon, and some of its beds are quarried at Lemont and Joliet.

There also lies, to the eastward of the axis and over this orderly succession, from above Ottawa to above Morris, the lower coal measures of the Carboniferous period, with some development to the north of the Illinois valley, but generally to the southeasterly.

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As should be anticipated, the general dip of the rocks above described is at r angles to the axis of upheaval, or from La Salle toward Lake Michigan. There are • less variations in thickness, flexture, dip, etc., the characteristic disposition only b here set forth.

Some of these rocks are porous or water-bearing, as, notably, the St. Peter's stone, from which the artesian supplies in the northeastern portion of the Stat drawn. The Potsdam sandstone, lying on a still lower horizon, but not outcroppin also tapped for water. Some springs are developed in the Cincinnati group, and als some of the numerous strata of the coal measures.

So far as these strata outcrop, or are cut into by the beds of streams, they furn springs and a uniform supply of water. So far as they constitute the immediate und lying rock, they absorb ultimately more or less of the rainfall, providing the superfici deposits are permeable. So far as the rocky strata are impermeable, they arrest th percolation of the water downward, and ultimately deliver it at some outcrop on a low level. Aside from the permeable rocks, some of the limestones are jointed or fissure through which the waters have dissolved channels of cavernous proportions. It is n known that any such conditions prevail in any of the strata of the northern portion the State.

It is apparent that the general dip of the strata is in the wrong direction for a lar supply of ground water to the Illinois valley. Had, for instance, the St. Peter's sandsto inclined in the proper manner, it might be furnishing a large supply of water fr Lake Michigan to the valley. The manner, however, in which Lake Michigan was form determines the dip of the strata in that direction.

If we consider the strata to the southwesterly of the axis of upheaval, we find later rocks occupying the larger proportion of the area of the State in a sort of trou in a direction from the vicinity of Rock Island to the Wabash, the earlier rocks fring the State upon the west, southwest and south, from above Burlington, upon the Mississi to near Shawneetown, upon the Ohio. In this geological basin or trough, the underly rock is about half in the upper coal measures, all to the eastward of the Illinois, about half in the lower coal measures.

The rim rock is of the Lower Carboniferous period, with some minor axes of heaval, disclosing the older rocks as the Devonian at Rock Island, Devonian and Sil ian in the vicinity of the mouth of the Illinois and below, and also in the southern of the State.

As we gather these ideas, we can infer where ancient lakes, valleys and watersh must have been, and where they would be now if the conditions had remained changed. The surface of the State and of the underlying rock has been profour modified, denuded, planed down and flexed, by the forces of at least two well as tained epochs, called "drift" or "glacial," and the topography defined by the debris lef these periods. To a large extent, no doubt, the valleys were eroded or their locati determined before these periods, especially on the main lines, though the detail top raphy was formed at these times. The arterial valleys were, however, greatly modif In one of these periods, the valley of the Mississippi, at Rock Island and at Keok was filled up, and the modern channel is in a new location, over rapids which pres forces are inadequate to plane down on the scale of the older valley. The Illinois ley in places was partially filled with drift or glacial deposits, and in some sma streams the forces of erosion have not since been adequate to their removal.

What may be called the first drift or glacial period, extended southward nearl the southern end of the State, and left deposits of clay with gravels and sands, debris of all the northern rocks to Lake Superior and even farther, from a few fee two or three hundred in depth. These are denuded in places, exposing the underl rock, eroded in valleys, covered by lacustrine deposits; but in general they are basis of soil throughout the glacial belt in northern latitudes. Rich in the proper r eral constituents, on the flat expanses of the original deposits flourished that ac vegetable life which determined the uniform features and fertility of the prairies.

This drift is more or less modified, and to that extent the gravels and sands are stratified, or otherwise arranged by water action, so that they are waterbearing under present conditions.

The second and last glacial period is much better defined, and its action, though far more limited, was more characteristic. At least, it left those changes which are nearer our time, more directly related to modern problems, and of more immediate interest in the upper basin of the Illinois, with which we are immediately concerned.

Suppose that a great glacier, a sea of ice, filled the bed of Lake Michigan, several hundred feet in thickness above its present level, overlapping the present shore lines far inland, extending well down into Illinois, with its general axis in the direction of the lowest level or along the course of the Illinois valley, shoving, however, outwardly in all directions to lower levels, or as the resisting forces permitted; suppose that this glacier, in its greatest extension, reached the line dividing the waters of the Fox from Rock river, Bureau creek from Green river, crossing the Illinois valley at Putnam, and extending southeasterly along the general line separating the waters flowing northerly from those flowing to the Mackinaw and Sangamon, between the Iroquois and Big Vermilion, and between the Kankakee and Wabash in Indiana; suppose that this great glacial field, in its southward movement, brought the grindings, the washings and the debris of all the northerly rocks in its course, and deposited the material at its melting fringe; suppose that for a period of time the borders did not change—that the forces of advance, just balanced by the melting conditions of climate, deposited a great moranic ridge of debris, that there are periods of comparatively rapid recession and again periods of equilibrium, throwing down concentric ridges; suppose that the enormous volumes of water, pouring at first down the slopes of the outer ridge and excavating there the valleys, at a later period drained inside the ridge, between it and the ice fringe, to the main drainage or the Illinois—then you have a general picture of the last glacial period in Illinois.

A relief map of northern Illinois would show these concentric ridges, most widely separated along the axis of movement, and closing on each other in a common ridge as we go north into Wisconsin, or easterly into Indiana or Michigan. Between them lie the tributary valleys, the marginal lines of glacial drainage, all concentrating from the north and from the south and from the east the flow of waters in the Illinois Valley. Like inner lines of defense, the great ridges succeed each other with subsidiary ridges and traverses which define the minor basins. As we approach Lake Michigan, the last great ridge, or the present rim of the lake basin, crosses the old outlet above Lemont, in the township of Palos and Orland, going eastward, between the Calumet and Kankakee, into Indiana and northward, as the west slope of the Desplaines watershed, into Wisconsin. In very recent times the Desplaines, like the Calumet, sent its waters to the lake, but alluvial deposits, probably assisted by the beaver, changed its flow in part down the old outlet valley.

During the last glacial period, the underlying rocks were generally denuded, though in places the drift of the preceding period, with its overlying soil and beds of humus, was left undisturbed. We should expect that the ridges would be largely as they were left, clay filled with boulders, gravel and sand, sometimes with irregular sand and gravel pockets; that their outer slopes should be steepest and their inner slopes gentle, and the valley of the stream close to the succeeding ridge; that the material should show more tendency to sorting or arrangement in beds of clay, gravel, etc., as the drainage line is approached; that there should be occasional ridge gaps, with plains of gravel and sand behind (like that at Plainfield, Will county, and of which Joliet Mound is a remnant below Joliet), where pent-up waters have poured out, leaving only the heavier material; that the summits of the ridges should be left with depressions in the mud axially at right angles to the ridge (the present lakes, ponds, marshes and bogs); that the underlying rocks should be scratched, ground and scored in the direction of the movement which the superficial deposits indicate, and that in these directions we should find the debris of the rock strata passed over. In all these things the expectation is fully verified.

A general ice cap covered the northern zones down to the international boundary, or below, and sent southward great tongues of glacial flow—one going out the head of Lake Superior, one out Green Bay, one out the bed of Lake Michigan, one out Saginaw Bay, which moved southward and lapped its debris with that of Lake Michigan in northern Indiana, and one out of Lake Erie toward the Wabash valley. Between these tongues are found no glacial deposits, no drift, the underlying rocks undisturhed, and the surface soil partaking of their character, fertile or otherwise, as in southern zones, rather than the uniform characteristics of the drift areas. Such driftless areas exist in northern Wisconsin, between the Superior and Green Bay tongues, and in southern Wisconsin and northern Illinois, between the Green Bay and Michigan tongues.

If, to this general conception of a northern ice cap with the limits stated, we add an ice cap at the southern pole no larger than now exists in arctic regions, we can see how such conditions would shift the centre of gravity of the earth sufficiently, how such masses would shift the waters northerly, so that an arm of the Gulf of Mexico would cover the site of Cairo and the southern part of the State.

Perhaps primitive man saw the last glacial period. The record is, however, upon the rocks, in the character and manner of the superficial deposits, in the the configuration in northern latitudes. Toward this general conception the scientific mind has been crystalizing for fifty years, and only by some such interpretation is what we see and find understandable. The astronomical physicist interprets the endless variation and recurrence of planetary movement in cycles of time, tells when these periods have occurred in the past and when they will recur in the future. The scientific explorer studies the predominating antarctic ice cap, investigates ice action in the far north, follows the glacial flow in the gulches of the great mountain chains, and sees there occurring as though yesterday in time, that which has produced the profound results, and which we have endeavored briefly to portray.

As we gather these general conceptions, understand the forces which have acted in the underlying rocks, their character and dip, comprehend how the superficial deposits have been made, their nature, extent and configuration, the changes in level and flexture of the earth's crust, we appreciate how basins have been defined and valleys formed, what to expect in flood and low water and the tendency of the changing conditions wrought by man. All this must be understood to make intelligible the hydrography of a river basin.

As we understand the forces and mode of action in the last glacial period over the area reached by the Lake Michigan glacier, we can see how the north and south tributary watersheds of the upper Illinois river are all arranged in parallel series, even to the minor basins. We can understand how little of the rainfall can go down farther than the surface has been frost-heaved and dessicated by the vegetable growth of ages, how there is little stratified drift and gravel; how water courses were arranged by the water action of the past, to equalize the flow to the streams how the permeable rocks derive their supplies in remote regions and furnish in limited amount the water which was precipitated ages ago.

In some basins, notably the chalk of England, water reaches the streams almost wholly as ground water giving an equable flow at all seasons. The same is characteristic of the Greene river in Kentucky, and of all streams of equable flow. The upper Illinois is supplied almost wholly by surface drainage, and under such conditions, the variations with changing season and year by year are most pronounced and the superficial changes effected through inhabitation will be most potent.

The Illinois Valley, at least in its later stages, was excavated by the glacial drainage gathered in by its upper tributaries, the great volumes of water from the melting ice cap conducted hitherward along the line of glacial depression and carrying in large quantity the grit to grind and chisel away the resisting strata. As these strata vary, so do the characteristics of the valley eroded therein, in width, grade and general features.

The valley from above LaSalle to Beardstown is cut in lower coal measures, easily erodable, and is consequently wide, with a rocky floor at a consideaable depth below the present surface of the bottoms. Below Beardstown Lower Carboniferous limestones continue to Columbiana, succeeded by Silurian rocks to the mouth, the strata less erobable,

the valley narrower and with more rugged escarpments. Throughout the whole 230 miles, the grade is very small, or such as is only due to an enormous volume of water carrying debris to remove by attrition.

Ascending from LaSalle, the waters and the debris were perhaps lessened in the glacial retreat, and when beyond the Chicago divide, clear water with less eroding force came. The valley is carved largely in the Silurian strata—more resisting than those encountered below—and the valley is narrow with heavier grades and precipitous descents.

Opposite Utica, the lower magnesian limestone carrying the water lime is developed, and the deep bed eroded in the coal measures below terminates abruptly. A steeper grade begins and is continued in the St. Peter's sandstone to two miles above Ottawa. Here the bed is again in the coal measures, a steep grade to Marseilles, or the chain of rocks near the mouth of the Kickapoo. Thence it is comparatively level and deep, the bed filled with debris, until the Cincinnati g oup of rocks is reached with a rocky bed to the streams, two or three miles above Morris. The limestone rock, however, at Marseilles is of limited thickness underlaid with fire clay, so the margin has been very narrow against a deeper erosion of this portion of the valley.

Cro-sing the Cincinnati limestone with some grade the Niagara limestone is met near the foot of Lake Joliet. Lake Joliet and Lake DuPage are simply two deep pools at the foot of steep slopes excavated by the great flow of glacial waters down the DesPlains and DuPage val eys. Rising from Lake Joliet, the e is a sharp slope in the resisting Niagara limestone of about eight feet per mile for ten miles to Romeo, thence a gentler grade to Walker's quarry, above Lemont, which is the summit of the rocky floor of the old channel and eight feet above low water in Lake Michigan.

Beyond this the general horizon of the rock deepens, its surface apparently irregular with superficial deposits of clay, hardpan, gravel and boulders, until in a few miles the rock dips well down under the site of Chicago. This description is also true in part of the Sag channel leading out through the Calumet region though the rock appears to lie at a greater elevation under the larger part of the Calumet district.

In the glacia re'reat beyond the southern borders of Lake Michigan, the waters pou ed out by both of these channels, uniting above Lemont. All the ridges about the head of the lakes are benched and these levels can be traced for long distances, and some of them are characteristic, as showing where the waters stood for a considerable period o ftime.

At a level, 30 to 35 feet above present low lake, is a well defined beach line extending from Evanston around into Indiana, which must have ma-ked the level of the lake for a long period of time, when the flow across the rocky floor of the old outlet could not have been ess than 20 to 25 feet deep and the volume probably greater than the present Niagara. This was then the outlet of the three upper lakes, Superior, Huron and Michigan when the conditions which determine volume of water were not radic-lly different from the present.

The circumstances which caused the abandonment of the old outlet, we will only allude to. The earth crust, relieved of the great ice weight, may have slowly risen until the flow was intercepted and the channel at Port Huron opened. It is supposed that the bed of Lake Michigan was fashioned in pa-t by erosion and in part by the flexture of the crust under the ice weight. The Huron barrier, virtually a moranic deposit, may have given away through long and increasing percolation, and drained the lakes down below the level of the outlet. The indications ar that the change was not prolonged over any considerable period of time but was measurably abrupt.

As the glacier retreated northward, the upper tributary valleys of the Illinois river uncovered and began to clear themselves of debris. The gradual retreat, the dim nishing supp y of water until it became measurably constant and the supply of debris, formed in the valley its own banks and flood plain—overflowed in summer—which now constitute the terrace, or second bottoms, traceable with some interruptions from Lake Joliet to the mouth of the river and furnishing the locations on which towns are built. The Hennepin bottom, the railway location from Bureau to Sparland, the site of Henry and the large fertile area behind it, Lacon, Pekin, Havana, Beardstown, all mark the level of

the old flood plain below LaSalle, from 30 to 40 feet above present low water and from 20 to 30 feet above the present bottoms, well above the highest waters of recent time.

These terraces mark the boundaries of the ancient stream flowing as the proper outlet of the three upper lakes with a volume greater, perhaps, than the present St. Lawrence. We have little information as to the depth below LaSalle, but from such examinations as have been made, a depth of 15 to 20 feet of mud and alluvium is passed through below the present low water before we strike the sands and gravels of the ancient stream bed. At Chillicothe, the gravel lies at 21 feet, and the rock floor of the valley at 36 feet below the level of the Copperas Creek pool.

The abandonment of the old outlet makes a radical change in conditions. A great stream bed, with its flow line well above present limits, carrying the waters in equable from a watershed of not less than 210,000 square miles flow—perhaps along with the gradually melting and retreating glacial accumulation of ages—is suddenly depleted and reduced to a local watershed of less than 12,000 square miles above Peru, with all its variations of flood and summer flow—such extreme variations as occur in a watershed almost wholly of surface drainage.

The local tributaries had become adjusted to the local drainage, had worked out their courses and grades in harmony with the conditions of water supply and the material of their beds. So the abandonment of the artery made no change except to steepen the grades in their lower reaches. But the great stream bed was not adapted to the changed conditions and must perforce shrink its dimensions and anjust its grade until the local volume of flow is in equilibrium with the forces of deposition—until from the spoils of the local drainage, the old stream bed is filled and reduced to present needs. This operation nature is now engaged in and will continue for ages until completed, unless man intervenes with a volume of water more uniform and in better harmony with the grade which now exists.

What is nature doing? Flling the old bed below LaSalle with alluvium, sand, ooze, steepening its grade, having already raised the bed of the stream from ten to fifteen feet above the old bed and filled in bottoms from 25 to 30 feet deep between the terraces or old banks. Every tributary is bringing its load and the main stream distributes the same or is choked thereby; yet the banks are only halfway up from low to high water while every alluvial stream in adjustment only tops its banks in extreme flood. Nature has a great task before it, a task longer than the perpetuity of nations, and meantime great areas of bottoms remain worse than useless, distilling disease.

Every upland stream carries its strip of higher ground across the bottoms, laving strips and patches to mark its former course which it may have abandoned to build up lower levels. Between are lakes, bayous, sloughs, marshes, a large proportion of the total area, flooded deep in high water, and building up with each year's light deposits; forbidding, unhealthy, stagnant, almost inaccessible reservoirs to feed the river in low water. Then there is the strip of higher ground along the river bank.

From Hennepin to Peoria, the tributaries are small, the total watershed very limited, and little detritus is carried across the bottoms to the main river. The valley filling is largely from the detritus of the upper river watershed which continually encroaches southward upon the remnant of the old stream represented by the broad and deep expanses from Chillicothe to Peoria. The large tributaries below have adjusted the conditions more nearly to their requirements, or the stream is in better harmony with its modern life below the Sangamon. But here backwater from the Mississippi complicates the flood conditions.

Above La Salle, in the St. Peter's limestone, the modern stream has eroded a bed commensurate with present requirements. Still farther up, through the coal measures, and to the Cincinnati limestone, a stream bed has properly worked out, partly by erosion in the rock, and partly by raising the bottoms through deposition. The grades are ample to accomplish such results, and from the reef above the Marseilles dam to above Morris the excavated bed seems to be filled in part by heavy debris.

The Desplaines above Lake Joliet has cut no channel in the rock; it has barely cleared away the floatrock and defined its course for a depth of one to two feet, and its borders have not been raised by silt deposits,—evidence that this stream has flowed southward

for a short time,—but a few hundred years at most. The rocky floor from Joliet to Lemont is covered only with the thickness of a turf, and the "twelve-mile level" from above Lemont to Summit, with its alternation of pool, drift material and rock, is the remnant of the past. The silts of the Desplaines watershed have gone lakeward, deposited in the Mud Lake region, and partially dammed the flow in this direction. Had the Desplaines gone southward ever since the abandonment of the ancient outlet, it would ere this have grooved itself in the rock, built up its banks, and reduced the prism of Lake Joliet to present requirements.

Thus, from the disposition of the rocks, from the glacial action, we may infer how the basins have been formed and the valleys defined; from the character of the superficial deposits and the underlying strata, we may judge the flood and low water conditions, and the effect produced by inhabitation; from the functions of the ancient valley, we may diagnose the constitutional disorders produced by present conditions, and prescribe the remedy.

## EFFECT OF INHABITATION.

Inhabitation may produce profound changes in the flow of the streams which drain a local watershed or basin, and, within limits, modify the climatological conditions. The nature and extent of these changes, the effect of inhabitation, as already inferred, is dependent largely upon the superficial features, the distribution and character of the drift or glacial deposits, and the nature and disposition of the underlying rocks.

In a region of steep slopes and scant covering of impermeable rocks, wooded, the protected surface, the humus and debris, absorbs and retains the falling waters, distributes them more equably. Yet there comes a time when this capacity is exceeded, or when the suaface may be frozen or impermeable, and also when a succession of dry seasons leaves no moisture, and the result is that the earliest records may show as great extremes of high and low water as the recent. After the clearing away of the forests, the slopes drain more readily and fully, the supply retained is less and sooner exhausted, and there recurs constantly those extremes of high and low water which were before phenomenal. The flow of water is more immediately dependent upon the meterological conditions. The slopes, too, are more readily erodable, the streams become torrential, and their beds choked with the unusual supply of detritus, which of itself increases the apparent volume and extent of overflow.

If a similar region is underlaid with permeable strata, then the rainfall percolates downward, except when in great excess or, when the surface is frozen—a rare circumstance under such conditions. The streams receive a more equable supply, and may even continue after successive years of dry weather, from the supplies stored in the sub-strata. Under these circumstances inhabitation may not materially change the natural order.

In a flat region, or one of gentle slopes, with impermeable, subsoil the water collects in the depressions or moves slowly over the surface as a thin sheet. If the fall of water is moderate it may never reach the streams, but evaporates; if large, a great volume will accumulate upon the surface, to finally reach the watercourses in larger floods than ever come from any other class of watersheds. Unless the ground is frozen, it takes heavy precipitation to start the streams, and in dry weather the flow, of course, ceases. the surface gives up the little moisture it may contain cracks and is capable of receiving considerable water before it again flows away.

If, during the ages, a few feet of the surface have become permeable through the action of frost, drought and vegetation, a soil or mold is formed; the depressions filled with absorptive peat or humus, or remaining as ponds and lakelets, the action is modified. After a drought, it may take even more water to so saturate the surface as to make contributions to streams, the flood volumes will ordinarily be less and the flow more prolonged, and except under extreme conditions the flow from lakelets, ponds and bogs may not entirely cease. Such areas are not usually timbered. This condition would be further conservative and distributive of flow.

Inhabitation drains the natural reservoirs which have been furnishing a scanty volume to the streams in dry weather. It ditches the lands and increases their porosity so that the surplus water is more readily collected and more rapidly carried away;

this is not all. The land, though more absorptive, does not have to become charged to the full capacity of the spaces between the particles, to overflow, as it were, but the waters percolate to the drains; the action is reservoir like, equalizing. The capacity to take rainfall is also greatly enhanced, and the precipitation must be rapid or frequent to overflow the ground for any length of time and to saturate it beyond a capacity for more in a brief time.

These conditions, with extreme precipitation or frozen ground, may not effect floods. After extreme drought, the flow will start sooner. In the ordinary case, the flow will come quicker, more gradually and last longer, but the result upon the stream will depend upon how far the reservoir action of the ditched lands will outweigh the destruction in large measure of the natural reservoirs. In any event the low water flow of the ordinary year is greatly lessened or wholly stopped, as the drained lands will not part with their moisture beyond a certain point, except through vegetation and ordinary evaporation. A diminution in the forest area, exaggerates the extremes, while its increase is conservative.

If we suppose the same general topography with shallow cut valleys, the substrata permeable, then the results will vary materially with the precipitation during the year, or during successive years. The tendency is to distribute results like permeable strata with steeper slopes, or with deeper cut drainage lines. The flow through permeable strata is necessarily slow, but is like flow everywhere, requiring grade to carry the water to some point of delivery. The general surface of this grade is called the ground water plane, and its height and slope vary with the supply of water, or with the season or year. Under the conditions of land stated, it lies necessarily close to the surface, so that heavy precipitation may cause the ground to be entirely filled, or to overflow, with flood conditions resembling those previously described, while the low water flow is well maintained. So from such surfaces, in wet years, heavy floods are to be expected, and again in other years, none at all. Inhabitation will drain such regions so as to lower or keep down the ground water plane, and to this extent may exaggerate flood conditions and diminish the supply for equable distribution without impairing the low water volume of the dryer years. Yet lowering the ground water plane leaves the ground above in a reservoir condition, so that the effect under some circumstances may be conservative as to flood exaggeration.

Such permeable grounds are usually more or less timbered. The clearing away exaggerates the surface drainage without any marked effect upon the low water volume of the streams.

The four general conditions discussed are typical. There are endless variations in the conditions of surface, configuration, subsoil, depth to rock and its character and disposition, the distribution of drainage lines, n different basins and even in the same watershed; differences in climatological conditions, in the amount and distribution of rainfall with the season, and with the years,—all factors in the flow from the watershed in wet and dry season, in flood and drought. As the flow of streams is studied, the hydrography of basin interpreted, all these things must be more or less appreciated and as the causes are apprehended the habits of the stream are understood.

As we understand the changes brought about by inhabitation in typical cases, we can apply the inferences to the condition that may prevail in any given basin, and thus reach results significant of the future. These may have a profound economic and sanitary importance and be well worthy of attention, with a view to correction or such provision as should precede rather than follow when necessity compels.

In general, it may be said, that the tilling of the surface, enables it to take the rainfall more readily, makes it more immediately absorptive than the prairie turf of centuries, often hard and compacted so as to shed the rainfall rapidly. At the same time, when the ground is saturated, the surface flow carries great quantities of material as silts to choke the stream bed or build up bottoms. This action is vastly exaggerated under the condition of frozen ground with melting snow, or the spring rains which settle the frost-heaved ground. So far then as inhabitation may exaggerate the floods, or decrease the low water, and with the vastly increased supply of detritus from the

tilled lands in any event, the streams themselves are placed under much more difficult conditions. In part, no doubt, recent popular ideas in regard to the change in the flow in s reams are due to this fact.

It may also be stated generally that winter may begin with rains, a melting snow, to freeze quickly and close the surface against absorption, and that this condition will produce spring floods in any region when the accumulated snows are melted, often with drenching rains, leaving even the underlylying soil devoid of moisture. Such a condition prevailed over a large portion of the upper Illinois basin in 1887. Heavy ice or snow water freshets, followed by a verv dry soil and as little land-water in the Illinois river at Morris (in May) as known for thirty years. This probably came almost wholly from the natural surface reservoirs.

It is no doubt true that all these effects of inhabitation react upon the meteorological conditions—to what extent is a matter of speculation. It is the general belief, west of the Missouri river, that the rainfall is increasing (there seems to be little or no doubt of it), and this result has been ascribed to the tilling of the ground, the increasing porosity and absorbing power of the surface. Such effects, if occurring in Illinois, would be less noticeable with the greater precipitation in this State. I is difficult to believe that the profound meterological causes can be materially changed, but the local cycle, subsidiary thereto, can no doubt alter in some degree.

Although the flow of local or tributary streams may be profoundly modified by inhabitation, this is true, in less degree, of the main stream or artery, the change being less with the area of basin considered.

The flood volume of a stream is never equal to the combined flood volumes of the tributaries, and with many tributaries and a large area, does not even approach such a volume. The several tributaries will not reach high water at the same time, nor will their floods reach the main stream conjointly; neither do they enter at the same point, but are distributed along the valley. The practical result is that the duration of the flood in the main stream is much lengthened, and the volume is correspondingly less than the aggregate of the tributaries. Alteration in the flood conditions of the tributaries will not materially change the time or order in the contribution to the main stream, and as the results are only partially cumulative the effect is relatively less. In many large basins no sensible change would probably occur.

The reverse is true, in a less degree, of the low water volumes. No two tributaries are in exactly the same condition as to low water at exactly the same time, but as the low water period is very much longer than that of floods, the results are more nearly cumulative. It is found, practically, that the low water volume in small basins is less per square mile than in large ones. Thus, the Mississippi at Grafton carries about four times the volume per square mile of its watershed as compared to the Illinois, though the conditions are not strictly similar.

Rains may not be uniformly distributed in any one year, nor in the same manner during the succeeding one; a considerable range in latitude may be covered, giving a very moderate and prolonged flood from the melting snow in streams running southerly, and cumulative results in those running northerly; basins may be differently shaped, thus collecting the waters rapidly and cumulatively, or slowly and distributively, a tributary basin may be subject to an extreme local flood, from extreme precipitation, which seldom exceeds the smaller areas at a given time. So from many causes, as the stream grows larger and drains a greater area, the extremes of low water and flood are relatively lessened, and the effects of inhabitation are less marked.

In all the results due to inhabitation, the detritus contributed to the main stream is greatly increased. The effect of this may be profound in a stream bed of little grade, and which, under previous conditions, had not yet adapted itself to its work. This, coupled with the diminished low water volume, has an important bearing upon the navigable utility of the stream in the future.

Under the previous head, the character of the upper Illinois watershed has been set forth—impermeable substrata, a good depth of permeable surface, flat or moderate slopes, with considerable bog, marsh and lake, and little timber, the main valley not adjusted to the drainage conditions below Utica. Inhabitation will increase floods, greatly reduce the minimum flow, multiply the amount of detritus. The tendencies will be destructive and most unhealthful in the lower valley. The conditions are presented more specifically, and in detail, ater in this section of the report.

## POPULATION DISTRIBUTION.

The project of supplying an additional volume of water to the Desplains and Illinois rivers from Lake Michigan at Chicago is of interest and great importance to the urban population of Cook county and to the population upon the watershed or basin of the Illinois river, or nearly two-thirds the population of the entire State of Illinois.

The area of the State is about 56,000 square miles.* The area of the basin of the Illinois is 27,914 square miles, of which 4,110 square miles lie in the states of Wisconsin and Indiana. The area draining to Lake Michigan in Lake and Cook counties is 1,141 square miles, of which 450 square miles are in the basins of the Calumet rivers in Indiana.

The population of the State, of Cook county and of the State at large for 1850, 1860, 1870, 1880 and 1888, is given in the following table:

| Date. | State. | Cook County. | State at Large. | Remarks. |
|---|---|---|---|---|
| 1850.......... | 851,470 | 43,385 | 808,085 | U. S. Census............ |
| 1860.......... | 1,171,951 | 144,954 | 1,026,997 | U. S. Census............ |
| 1870.......... | 2,539,891 | 349,966 | 2,189,925 | U. S. Census............ |
| 1880.......... | 3,077,871 | 607,524 | 2,470,347 | U. S. Census............ |
| 1888.......... | 3,700,000 | 1,071,020 | 2,629,000 | School Census.......... |

This table shows that the large increase in the growth of the State is in Cook county. The detailed exhibit given later shows it to be confined to about 250 square miles, or to Chicago and its immediate vicinity.

The population statistics are presented in two compilations, one pertaining to the basin of the Illinois river and the other to the basin draining to Lake Michigan. The latter gives various aggregate useful in considering the area and the population which may be served by a drainage channel to the Desplaines and Illinois river: and, also, the probable growth of such areas or districts in the immediate future.

### Illinois River Watershed.

The area of the Illinois river basin is 27,914 square miles. The population in 1880 was about 1,200,000, and the increase to 1888 about 70,000.

The compilation has been completed only down to the Copperas Creek dam, and is subject to revision. The area is 15,254 square miles, and the total population in 1880 was 679,273. The increase to 1888 was 43,475.

The following tables are made up from the United States census of 1880, giving the population of counties, and also of cities, towns and villages. They present the results in detail for each important tributary basin, and also for the aggregate area of the several basins. In compiling these results, all communities of over 5,000 population are classified as cities, those from 5,000 to 500 as towns, and those of 500 to 50 as villages, the remainder being rural. The tables are accompanied by such remarks as will serve to interpret their significance.

The changes to 1888 are computed from the county returns of the school census as reported by the State Superintendent. These returns are for the population under twenty-one years of age. The reports for Cook county and for the city of Chicago, give also the total population of those districts.

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U. S. Census of 1880.

The State Superintendent estimates the total population of the State at 3,700,000, the number under twenty-one being 1,669,640. The population in Cook county is 1,071,020, the number u der twenty-one being 446,953. The population in the State at large would be 2,629,000, and the number under twenty-one 1,222,687. The population would then be, outside of Cook county, 2.15 times the number under twenty-one years of age. This ratio is applied to the county returns in estimating the population for 1888.

T e following table gives the population of counties situated wholly or in part upon the Illino's river watershed, down to the Copperas Creek dam, about 26 miles below Peoria bridge, or the foot of Peoria lake.

ILLINOIS RIVER WATERSHED COUNTIES.

| County. | 1880. | 1888. | Change. | Remarks. |
|---|---|---|---|---|
| McHenry | 24,914 | 24,308 | —606 | |
| Lake | 21,299 | 21,283 | — 16 | |
| Kane | 44,956 | 52,761 | +7,805 | |
| DuPage | 19,187 | 22,052 | +2,865 | |
| Cook | 30,924 | 36,603 | +5,679 | All west of meridia of west boundary of Cicero, and including also the townships of Rich and Bloom |
| Will | 53,431 | 61,746 | +8,315 | |
| Kankakee | 25,050 | 28,208 | +3,158 | |
| Iroquois | 35,457 | 34,660 | —797 | |
| Ford | 15,105 | 16,358 | +1,253 | |
| Livingston | 38,453 | 38,558 | +105 | |
| Grundy | 16,738 | 21,689 | +4,951 | |
| Kendall | 13,084 | 11,216 | —1,868 | |
| DeKalb | 26,774 | 23,826 | —2,948 | |
| LaSalle | 70,420 | 80,244 | +9,824 | |
| Bureau | 33,189 | 33,587 | +398 | |
| Putnam | 5,555 | 4,539 | —1,016 | |
| Marshall | 15,036 | 13,556 | —1,480 | |
| Woodford | 21,630 | 22,262 | +632 | |
| Peoria | 55,427 | 60,236 | +4,809 | |
| Tazewell | 29,679 | 29,442 | —237 | |
| McLean | 60,115 | 62,963 | +2,848 | |
| Total | 656,823 | 700,097 | +43,274 | |

It will be noticed that those counties without large towns or cities, or mining industries, have decreased in population, while those counties containing large communities, or mines, have increased. Such cities as Joliet, Aurora, Streator, Bloomington and Peoria, have grown rapidly, far more so than indicated by the increase in population of the counties in which they are situated. The increase in Grundy county is due to coal mining. A large community has grown up at Spring Valley and vicinity, in Bureau county, but the balance of the county has considerably decreased. La Salle county contains several cities which have grown more or less, as, likewise, Kane county. The portion of Cook county given has decreased largely, except in four townships, containing suburbs immediately west of Chicago. The same is also true of Du Page county.

In all these counties the decrease is assignable to special causes, and it is found that the urban increase is considerably in excess of the county increase,—in other words, that the centers of population have grown at the expense of the country. The rural population seems to have decreased quite generally,—from three to five to the square mile. In many cases, too, the villages and small towns appear to have decreased. Taking the normal growth of the country at large, the growth should not have been less than 25 per cent for the past eight years, or the increase in the counties tabulated should have beeen 164,000, instead of 43,475.

The absolute loss in growth in rural population is no doubt partially due to the remarkable growth of Chicago, but more largely to emigration to the new territory in the west, and it is probable that this movement will continue for twenty or thirty years, or until all the new lands are taken up, when the rural population will increase in density with a subdivision of farm areas. The change in distribution of population as between

rural and urban populations is doubtless due, in part to the increased application of machinery to agriculture, by which the necessary labor can be performed by fewer hands; in part to the rapid changes in transportation facilities, and in the methods of doing business, by which the needs of the county can be served from fewer and larger centers; in part to the increasing comforts of urban life, and the greater ease with which lands can be held and managed from the towns, and perhaps from that economic policy which has so greatly stimulated manufactures. The significant fact is the growing need of sanitary provision with urban increase, and the number of cities of large size which the Illinois river basin will contain. It is also worthy of note that Cook county contains one-half of the urban population of fhe State, as gathered in communities of sufficient size to require special sanitary consideration and provision.

In distributing the population between the several watersheds. after all attainable information is used, considerable judgment must be exercised, especially in regard to the increase during the past eight years. The results, however, as given by aggregates, can not be materially in error. In all cases, when not otherwise specified, the population in 1880 is intended.

The areas are computed from the large county atlas maps of Illinois, and from the State maps of Indiana and Wisconsin. The watershed line of the Desplaines above Lockport is from actual survey.

KANKAKEE RIVER BASIN, 1880.

| Basin. | Area. | Cities. | | Towns. | | Villages. | | Rural. | | Total population. | Change in pop. 1888. | Counties. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No. | Pop. | No. | Pop. | No. | Pop. | Per mile. | Pop. | | | |
| Iroquois.... | 2,000 | .. | ...... | 11 | 10,218 | 31 | 5,567 | 20 | 40,790 | 56,575 | —1,124 | Indiana, Iroquois, Ford, Kankakee, and Vermilion...... |
| Upper Kankakee...... | 2,540 | 1 | 6,195 | 11 | 9,814 | 50 | 8,108 | 23 | 57,752 | 81,869 | +3,131 | Indiana, Iroquois, Kankakee and Will |
| Lower Kankakee...... | 606 | 1 | 5,651 | 3 | 3,080 | 3 | 670 | 27 | 16,297 | 25,698 | +2,302 | Kankakee, Will, etc.. |
| Totals .. | 5,146 | 1 | 11,846 | 25 | 23,112 | 84 | 14,345 | 22⅓ | 114,839 | 164,142 | +4,308 | |

The Iroquois and Kankakee basins in indiana are as follows:

| Designation. | Kankakee. | | Iroquois. | | Totals. | |
|---|---|---|---|---|---|---|
| Area—Square Miles. | 2,212 | | 828 | | 3,040 | |
| Cities ........................................ | 1 | 6,195 | .... | ............ | 1 | 6,195 |
| Towns........................................ | 10 | 8,777 | 4 | 3,429 | 14 | 12,206 |
| Villages ........................................ | 43 | 6,557 | 8 | 1,155 | 51 | 7,712 |
| Rural ........................................ | .... | 49,278 | .... | 13,654 | .... | 62,932 |
| Total population...................... | .... | 70,807 | .... | 18,238 | .... | 89,045 |

A large proportion of the Iroquois and Kankakee watersheds in Indiana is marshy, and with a sparse population. A considerable proportion of the headwaters of the Kankakee is in well populated territory, with some growing communities. Concerning the changes in population in the adjacent counties of Illinois and the cbaracter of the territory in Indiana, the population for 1888 is inferred. Considerable shifting of population has occurred from the country and villages to the larger towns and cities, and several stations on new railway lines have been established.

Below the great dam, just above Wilmington, the area is 220 square miles and the population, including Wilmington, 7,550, of which 5,500 is rural. Down to a point just above the city of Kankakee, 22 square miles and about 600 rural population should be added to the sum of the Iroquois and upper Kankakee basins. Down to Momence, the

...nkakee in Indiana should be increased by 130 square miles and 3,800 population, of ...hich 654 are in three villages.

DESPLAINES RIVER BASIN, 1880.

| Basin. | Area | Cities. | | Towns. | | Villages. | | Rural. | | Total population.. | Change in pop. 1888. | Counties. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No. | Pop. | No. | Pop. | No. | Pop. | Per mile. | Pop. | | | |
| Upper Desplaines... | 342 | .. | ...... | 1 | 632 | 13 | 1,470 | 26 | 8,956 | 11,058 | ........ | Wisconsin, Lake Co. |
| To Summit. | 292 | .. | ...... | 6 | 4,513 | 16 | 3,008 | 39 | 11,384 | 18,905 | +5,152 | Cook, DuPage........ |
| To Joliet.... | 176 | .. | ...... | 3 | 4,607 | 8 | 1,270 | 34 | 6,080 | 11,957 | +2,488 | Cook, DuPage, Will. |
| To L. Joliet. | 130 | 1 | 11,657 | 1 | 524 | 3 | 526 | 33 | 4,340 | 17,047 | +8,315 | Cook, Will............ |
| To Ill. River | 452 | .. | ...... | 5 | 5,507 | 11 | 2,546 | 31 | 14,137 | 22,190 | +1,665 | Will, DuPage........ |
| Total.... | 1,392 | 1 | 11,657 | 16 | 15,783 | 51 | 8,820 | 32 | 44,897 | 81,157 | +17,620 | |

The basin includes the area tributary to the Illinois and Michigan Canal west of the the range line through Summit and the Ogden-Wentworth dam.

The basin in Wisconsin is as follows:

| | | |
|---|---|---|
| Area, square miles .............................................................. | | 136.4 |
| Villages, 6............................................................................ | 810 | |
| Rural population ..................................................................... | 3.600 | |
| Total population................................................. | 4,410 | |

The population in Lake county has not materially changed in eight years, and it is assumed that the conditions are the same in Wisconsin, so the total population in the upper Desplaines show no increase. If there is any change, it is in the growth of urban population at the expense of the rural districts.

The purely rural districts of Cook county have decreased. The townships of Maine, Leyden, Proviso, and the north tier of sections in Lyons contain suburbs of Chicago and show an increase. Suburbs in DuPage also give an increase. The net increase in the basin from Lake county to Summit, is 5,152.

From Summit to Joliet the increase is almost wholly at Lemont, with some additions from suburbs in DuPage county.

The increase in the basin to Lake Joliet is assumed at that for Will county. It is known, however, that Joliet has doubled in population, or the increase is greater than assumed.

The increase in the DuPage basin is due to Chicago suburbs, and is assumed as the entire increase to the Illinois river, the junction with the Kankakee.

The DuPage river basin is as follows:

| | | |
|---|---|---|
| Area, square miles.............................................................. | | 366 |
| Towns, 5.............................................................................. | 5,507 | |
| Villages, 10........................................................................... | 2,234 | |
| Rural population ..................................................................... | 11,409 | |
| Total population .................................................. | 19,190 | |
| Increase in 1888.................................................... | | 1,665 |

FOX RIVER BASIN, 1880.

| Basin. | Area. | Cities. | | Towns. | | Villages. | | Rural. | | Total population... | Change in pop., 1888 .. | Counties. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No.... | Pop. | No.... | Pop. | No.... | Pop. | Per sq. mile. | Pop. | | | |
| Wisconsin.. | 932 | .. | ...... | 6 | 10,381 | 28 | 4,155 | 32 | 29,746 | 44,282 | ........ | State of Wisconsin.. |
| To Elgin.... | 610 | .. | ...... | 4 | 4,330 | 22 | 4,623 | 26½ | 16,186 | 25,139 | —1,190 | M'Henry, Lake, Kane, Cook.............. |
| To Aurora.. | 200 | 1 | 8,789 | 3 | 5,415 | 6 | 1,062 | 32 | 6,460 | 21,726 | +3,832 | Kane, Cook, DuPage. |
| To Millingt'n | 420 | 1 | 11,875 | 1 | 2,448 | 14 | 3,507 | 25 | 10,616 | 28,446 | +3,036 | Kane, DuPage, Kendall, DeKalb........ |
| To Ill. River | 538 | .. | ...... | 4 | 5,059 | 8 | 1,417 | 27 | 14,637 | 21,113 | —600 | LaSalle, Lee, DeKalb |
| Totals .. | 2,700 | 2 | 20,664 | 18 | 27,633 | 78 | 14,764 | 28¾ | 77,645 | 140,706 | +5,078 | |

The population of 18e8 in counties bordering Wisconsin does not indicate any material change since 1880 of the population of the basin in Wisconsin.

Aurora, Elgin and Batavia have about doubled in population and Geneva and other towns have notably increased. The rural population has decreased. The net results are shown in the table. The change in the aggregate is less than four per cent.

The statistics for the basin in Wisconsin are given in the first line of the above table.

ILLINOIS RIVER BASIN, 1880.
(Omitting the Desplaines, Kankakee and Fox.)

| Basin. | Area. | Cities. | | Towns. | | Villages. | | Rural. | | Total population.... | Change in pop., 1888 .. | Counties. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No... | Pop. | No... | Pop. | No... | Pop. | Per sq. mile. | Pop. | | | |
| AuxSable to Morris.... | 218 | .. | ...... | .. | ...... | 4 | 891 | 25 | 5,523 | 6,414 | —900 | Will, Kendall, Grundy |
| Mazon to Morris.... | 540 | 1 | 5,524 | 4 | 3,557 | 9 | 1,688 | 26 | 14,093 | 24,862 | +4,846 | Grundy, Livingston, Will, Kankakee .... |
| ToM'rseilles | 202 | .. | ...... | 2 | 4,224 | .. | ...... | 26 | 5,326 | 9,550 | +200 | Grundy, LaSalle ..... |
| To Fox Riv. | 31 | .. | ...... | 1 | 1,882 | .. | ...... | 27 | 838 | 2,720 | +400 | LaSalle ............... |
| Below Utica | 136 | 1 | 7,834 | 1 | 767 | 1 | 135 | 27 | 3,674 | 12,410 | +4,000 | LaSalle ............... |
| L. Vermilion R. to Peru | 165 | 1 | 7,847 | 1 | 4,142 | 2 | 380 | 27 | 4,451 | 16,820 | +2,000 | LaSalle. ............. |
| Vermilion R to Peru... | 1,317 | 1 | 5,157 | 5 | 7,005 | 25 | 4,564 | 26 | 33,987 | 50,713 | +2,264 | LaSalle, Livingston, McLean, etc ........ |
| Total.... | 2,609 | 4 | 26,362 | 14 | 21,577 | 41 | 7,658 | 26 | 67,892 | 123,489 | 12,810 | |

The population in the mining districts and in the larger towns and cities is greater than the table indicates, as the rural population has sensibly decreased. Streator has grown notably. Ottawa has also grown considerably. The mining districts in Grundy and adjacent counties have increased notably. Considering all these matters the net change is estimated as given in the table. The total increase is about ten per cent.

The Vermilion basin above Streator gives quantities approximately as follows:

| | | |
|---|---|---|
| Area, square miles.................................................. | | 1,105 |
| Villages, 21.......................................................... | 4,155 | |
| Towns, 4.............................................................. | 6,501 | |
| Rural.................................................................. | 28,090 | |
| Total population................................................ | | 38,746 |

No material change is noted for 1888.

ILLINOIS RIVER BASIN, 1880.
(LaSalle to Copperas Creek Dam.)

| Basin. | Area. | Cities. | | Towns. | | Villages. | | Rural. | | Total population... | Change in pop. 1888. | Counties. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No.. | Pop. | No.. | Pop. | No.. | Pop. | No. pr. m | Pop. | | | |
| To Hennepin......... | 162 | 1 | 5,057 | .. | ...... | 3 | 683 | 26 | 4,241 | 9,981 | +4,584 | La Salle, Putnam, Bureau............. |
| To Bureau Creek..... | 480 | .. | ...... | 3 | 4,929 | 11 | 2,805 | 27 | 12,840 | 20,574 | —1,880 | Bureau, Lee......... |
| To Henry dam....... | 300 | .. | ...... | 2 | 1,534 | 5 | 1,431 | 24 | 7'169 | 10,134 | —1,240 | La Salle, Putnam, Marshall, Bureau... |
| To Chillicothe...... | 446 | .. | ...... | 3 | 5,455 | 9 | 1,640 | 24 | 10,869 | 17,964 | —1,430 | Marshall, Wood.ord, Putnam, Bureau... |
| To foot of Peoria L'k | 244 | .. | ...... | 2 | 2,333 | 7 | 1,051 | 22 | 5,306 | 8,690 | —587 | Woodford, Peoria, Tazewel .l......... |
| To Pekin... | 352 | 1 | 29,259 | 3 | 3,441 | 6 | 778 | 32 | 11,363 | 44,841 | +5,000 | Tazewell, Knox, Peoria ................. |
| ToCopperas Creek dam | 206 | .. | ...... | .. | ...... | 7 | 898 | 32 | 6,568 | 7,466 | —600 | Peoria, Fulton....... |
| Mackinaw R. to dam. | 1,217 | 1 | 5,998 | 5 | 5,257 | 22 | 4,475 | 28 | 34,399 | 50,129 | —188 | Tazewell, McLean, Woodford, etc..... |
| Total...... | 3,407 | 3 | 40,314 | 18 | 22,949 | 70 | 13,761 | 27 | 92,755 | 169,779 | —3,659 | |

A general increase in towns and cities and a decrease in rural population has occurred. The principal increase is in Spring Creek valley, a mining district of Bureau county and in the city of Peoria.

The following general table gives the aggregate results for the entire basin down to Copperas Creek dam.

The aggregate basin of the Illinois in Indiana and Wisconsin is as follows:

| | | |
|---|---|---|
| Total area, square miles | | 4,110 |
| 1 city | 6,195 | |
| 20 towns | 22,587 | |
| 85 villages | 12,677 | |
| Rural | 96,278 | |
| Total population | | 137,737 |

These quantities, taken from the aggregate of the table, give the statistics as to the basin within the State of Illinois.

ILLINOIS RIVER BASIN. (Recapitulation.)

| Basin. | Area. | Cities. | | Towns. | | Villages. | | Rural. | | Total population | Increase, 1888 | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No. | Pop. | No. | Pop. | No. | Pop. | No. pr. sq. m. | Pop. | | | |
| Desplaines | 810 | .. | ....... | 10 | 9,752 | 37 | 5,748 | 32 | 26,420 | 41,920 | 7,640 | To Joliet |
| Desplaines | 1,392 | 1 | 11,657 | 16 | 15,783 | 51 | 8,820 | 32 | 44,897 | 81,157 | 17,620 | To Kankakee River |
| Kankakee R | 6,538 | 3 | 23,503 | 41 | 38,895 | 135 | 23 165 | 24½ | 159,736 | 245,299 | 21,928 | To Illinois River |
| Illinois Riv. | 7,529 | 4 | 29,027 | 48 | 48,558 | 148 | 25,744 | 24½ | 185,516 | 288,845 | 26,474 | To Ottawa |
| Fox River | 10,229 | 6 | 49,691 | 66 | 76,191 | 226 | 40,508 | 25½ | 263,161 | 429,551 | 31,552 | To Ottawa |
| Illinois Riv. | 11,847 | 9 | 70,529 | 73 | 88,105 | 254 | 45,587 | 26½ | 305,273 | 509,494 | 39,816 | To Peru |
| Illinois Riv. | 12,789 | 10 | 75,586 | 78 | 94,568 | 273 | 50,506 | 25¾ | 329,523 | 550,183 | 41,280 | To Henry |
| Illinois Riv. | 13,479 | 10 | 75,586 | 83 | 102,356 | 289 | 53,197 | 25½ | 345,698 | 576,837 | 39,263 | To Peoria |
| Illinois Riv. | 15,254 | 12 | 110,843 | 91 | 111,054 | 324 | 59,348 | 26 | 398,028 | 679,273 | 43,475 | To Copperas Creek |

It will be noticed that over one-half the increase in population is in cities and towns upon the Fox and Desplaines, and within a comparatively short distance of Chicago.

The increase in urban population in cities and towns is probably double the aggregate increase given for the total basin.

The urban population in 1880 was about 40 per cent of the total population. At the present time it appears to be about 50 per cent.

LAKE MICHIGAN WATERSHED.

The 16 townships of Cook county already tabulated,—all west of range line through Summit and west boundary of Cicero, and also Rich and Bloom,—have an area of 547 miles, with a population of 30,924 in 1880, and 36,603 in 1888. If Thornton, Bremen, the west four tier sections in Worth, and New Trier, be added, it will include all of Cook county outside what is usually called the Metropolitan area, a total area of 669 square miles with a population of 38,670 in 1880 and of 46,354 in 1888. The Metropolitan area includes 270 square miles, and a population of 568,854 in 1880, and of 1,024,643 in 1888.

The area draining into Lake Michigan is in two basins, the Chicago river, extending into Lake county, and the Calumet, reaching with its branches into Will county and into Indiana.

The area draining into the Chicago river north and west of the Metropolitan area is 87½ miles, including a population of 3456 (two villages of 285 population included), from and the Metropolitan area 202 miles with a population of 559,408 a total area of 289½ miles with a population of 562,864. In 1888 the population had increased 415,830 in the Metropolitan area and diminished 185 outside, a total increase of 415,645, and a total population of 978,509.

The area draining to the lake direct, north of the Metropolitan area, in Cook and Lake counties, is 63 miles, with a population as follows:

| | |
|---|---|
| Towns, 4 | 6,648 |
| Villages, 3 | 950 |
| Rural | 2,306 |
| Total population | 9,904 |

This had increased 1297 in 1888, and the total population was 11,201.

The area outside the Metropolitan district, in Cook and Will counties, and tributary to the Calumet, is 270 square miles with a population as follows:

| | |
|---|---|
| Towns, 2 | 1,042 |
| Villages, 10 | 2,488 |
| Rural | 8,912 |
| Total population | 12,442 |

This had increased 497 in 1888.

The Grand Calumet in Indiana is included in the summary of the Calumet river. Its drainage is uncertain, but, under usual circumstances, into Illinois. The total area is 450 square miles with a population as follows:

| | |
|---|---|
| Towns, 4 | 7,420 |
| Villages, 18 | 3,178 |
| Rural | 10,069 |
| Total population | 20,667 |

The increase to 1888 is probably immaterial.

The Metropolitan area draining to the Calumet is 68 square miles, with a population of 9446 in 1880, increased to 49,405 in 1888.

The total Calumet basin is 788 miles, with a population of 42,555 in 1880, and of 83,011 in 1888.

The total area going to the lake from the Illinois frontage is 1141 miles. The total population was 615,323 in 1880, and 1,072,721 in 1888.

The metropolitan district has a length from north to south of 28½ miles, and an extreme width of 13½ miles, the area being 270 square miles. The population in 1880, 1886 and in 1888, and in Cook county at large, is as follows:

| Designation. | Area. | 1860 | 1870 | 1880 | 1886 | 1888 |
|---|---|---|---|---|---|---|
| Metropolitan | 270 | 121,949 | 319,640 | 568,854 | 878,057 | 1,024,643 |
| County at large | 669 | 23,005 | 30,326 | 38,670 | 39,345 | 46,377 |
| Cook county | 939 | 144,954 | 349,966 | 607,524 | 917,402 | 1,071,020 |

The population outside the Metropolitan area which pertains to Chicago, or is purely suburban, will make the total city and suburban population equal to 1,039,000.

The population on the Metropolitan a-ea in 1888 was distributed as follows: The statistics are given by congressional townships, as in school census, except where they overlap the city.

METROPOLITAN DISTRICT.

| Designation. | Area. | Population. | Remarks. |
|---|---|---|---|
| Niles | 23 | 2,850 | |
| Evanston | 10 | 11,485 | |
| Jefferson | 35 | 11,409 | Omitting sec. 36, ann'xed to Chicago |
| Lake View | 11 | 42,339 | |
| Cicero | 25 | 13,926 | |
| Lyons and Lake | 36 | 1,907 | |
| Lake and Hyde Park | 35 | 97,671 | To 87th street |
| Wor'h | 12 | 2,340 | Two east tier of sections |
| Calumet and Hyde Park | 36 | 22,617 | |
| South Chicago | 10 | 15,448 | |
| Outside Chicago | 233 | 221,992 | |
| Chicago | 37 | 802,651 | Including sec. 36, Jefferson |
| Total | 270 | 1,024,643 | |

If a district bounded by two miles north of city limits, the west boundary of city extended north and south and three miles south of city limits, be taken, it will have an area of 69 square miles and a population as follows:

| | | |
|---|---|---|
| North of city limits | 43,347 | |
| South of city limits | 81,728 | |
| | | 125,075 |
| Chicago | | 802,651 |
| Total | | 927,726 |

The greater proportion of the population outside the city limits is on the adjacent 32 miles north and south, and the growth is more strongly in these directions than to the west.

If a sanitary district be assumed so as to conform to political boundaries so far as the watershed will permit, it may be delimited as follows: North, one mile south of Evanston and Niles; west, along range line west of Jefferson and Cicero to south line of Lyons; south, along south line of Lyons and Lake to one mile east of Western ave., then northeasterly to Jackson Park. The area of such a district is 161 square miles, of which 52 square miles are sewered.

The population of this district in 1888 was 959,300. The district north had 15,935 on 41 square miles. The Calumet district had 49,405 on 68 square miles.

The population of the district in 1886 was approximately 824,000. In 1880, it was 549,20 , the district north having 10,200 and the district south 9,450. The population in the sanitary district was 310,177 in 1870, and 117,442 in 1860.

Should the district be extended down the Desplaines to the boundary of Lyons, about 23 square miles additional may be included and about 1,200 population in 1888.

The population in the Sanitary district is distributed approximately as follows:

| | 1886. | 1 8. | Remarks. |
|---|---|---|---|
| Tributary to lake, practically all sewered | 86,000 | 1 7,000 | |
| Sewered to Chicago river and branches | 697,000 | 800,000 | |
| Tributary to river, but unsewered | 41,000 | 42,300 | |
| Total population | 824,000 | 959,300 | |
| North of Madison street | 322,500 | 400,000 | Sewered. |

There is some sewerage in Cicero, tributary to the Ogden-Wentworth ditch and thus to the river system, which is not considered in the above.

All the population tributary to Chicago river and branches is also tributary to the Illinois and Michigan Canal, by means of the circulation occasioned in the North Branch by the Fullerton avenue conduit, whereby its contents are discharged into the South Branch and, with the sewage of the South Branch, carried to the canal by means of the circulation induced by the pumping works at Bridgeport. There is a small population tributary to the North Branch above Fullerton ave., but there is little sewage as yet from this source. This is moved down by the land water which is very little at low water. The population tributary to the South Fork was 75,000 in 1886. This has increased somewhat in 1888. This fork has only the circulation due to storm water and the water supply. Little sewage enters to the West Fork and this is sufficiently circulated at present by the water through the Ogden-Wentworth ditch.

The estimates of population north of Madison street bridge are useful in interpreting the condition of the river at that point.

Other sanitary districts are feasible in Cook county. The Calumet basin is a natural district which may be sewered by a channel drawing water from the lake and passing through the Sag to a junction with the Desplaines channel. An Evanston district on the north is possible, also drawing water from the lake and tributary to a Chicago channel. The Desplaines river basin immediately above Summit is an additional district which can be drained in a different manner. Growth of population will, in time, demand proper provision in all these districts.

## POPULATION INCREASE.

The indications are all that the rural or country population is decreasing, the increase being confined to the larger communities and the mining districts. The aggregate increase in the State outside of Cook county is small, some 159,000, when it should be about four times as great. Even including Cook county with its great growth, the aggregate increase for the entire State is still nearly 200,000 short of the normal increase for the whole country.

The causes which may be assigned for this condition have been already discussed. It does not seem probable that the growth will become normal for twenty or thirty years or until the arable lands in the territories and new states are occupied, if the present economic conditions are to continue.

If the present population of the metropolitan area be taken at 1,025,000, the increase in two years has been 147,000, and for eight years 456,000. The probable population for 1890 may be assumed at 1,175,000, an increase of 606,000 in ten years, or greater than the population of 1880.

The population of the sanitary district assumed has increased 410,000 in eight years, and 135,000 in two years. The population in 1888 was 959,000, and the prospective population in 1890 is 1,090,000.

The population of the city has increased 300,000 in eight years, and 100,000 in two years, including 10,000 annexed since 1886. The probable population on the present city area is 890,000 in 1890.

The population of Cook county was 1,071,000 in 1888, a growth of 464,000 in eight years, and of 154,000 in two years. The probable population in 1890 may be assumed at 1,230,000, or more than double that of 1880.

If an increase of 200,000 be assumed for the State outside of Cook county, or 2,670,000 in 1890, the total population will be 3,900,000, of which Cook county will contain 31½ per cent. In 1900 Cook county will contain about 40 per cent of the total population of the State. After that the relative increase will probably be slower, and it is doubtful if Cook county ever reaches 50 per cent. of the State.

In considering the growth of population, the entire community should be taken to ascertain the normal rate. The growth on any given part of a metropolitan area is apt to be spasmodic for any rapid increase or boom in a given direction is soon arrested by rapid appreciation of property or other causes. Taking communities as a whole, their growth by decades is remarkably steady after they reach a certain stage.

If the community centered around New York be taken, the growth has not varied materially since 1840, from 470,000 per decade; Philadelphia, except for the civil war, 180,000; Boston, 100,000, and St. Louis, about the same as Boston since 1850. These increments show a tendency to some increase for this decade. These results indicate that an increment does not diminish after a certain period of growth, or a community has obtained its majority. There is no reason, therefore, to suppose that Chicago will ever diminish its rate of 600,000 per decade, having attained that rate in the present decade. If the rate for the last two years be taken, the deceninal increase will be at the rate of 750,000.

In the growth of cities, however, the decennial constant is approached gradually. The past growth of Chicago as yet shows no tendency to constancy, as the past three decades have been 200,000, 250,000 and 600,000 respectively. The great fire probably reduced the increase 1870-80 by 150,000. Although in the periods before a constant rate is attained irregularity is often noticeable, still the indications are that Chicago will continue to increase its rate for some time to come.

The statistics of population for the last five two-year periods when reduced to a normal rate, show that the increment is increased 15,000 each two years; in other words, that the increment of 90,000 for 1880-82 has increased to 150,000 for 1888-90. The last

column of the following table gives the future population by this rule, while the first two columns give the constant rate as in the older cities, the first at 600,000 per decade and the second at 750,000. The figures indicate the population in thousands.

METROPOLITAN AREA.

| Year. | Increment 600,000 per decade. | Increment 750,000 per decade. | Normal Growth. |
|---|---|---|---|
| 1890 | 1,175 | 1,175 | 1,175 |
| 1892 | 1,295 | 1,325 | 1,340 |
| 1894 | 1,415 | 1,475 | 1,520 |
| 1896 | 1,535 | 1,625 | 1,715 |
| 1898 | 1,655 | 1,775 | 1,925 |
| 1900 | 1,775 | 1,925 | 2,150 |
| 1902 | 1,895 | 2,075 | 2,390 |
| 1904 | 2,015 | 2,225 | 2,645 |
| 1906 | 2,135 | 2,375 | 2,915 |
| 1908 | 2,255 | 2,525 | 3,200 |
| 1910 | 2,375 | 2,675 | 3,500 |
| 3,000,000 in | 1,920 | 1,915 | 1,907 |

If the causes of Chicago's rapid growth are fully considered there is no reason apparent why it should not continue somewhat as in the last column until a population of three million or more is attained. Then she should continue to grow with the increasing density of the country at the normal rate of 30 to 33 per cent. per decade, or at 25 per cent. if emigration ceases. This means that the decennial increment is not likely to be arrested short of one million for each ten years. If this be the case, Chicago will overtake the New York community in 20 to 25 years, and in time become the biggest city of the world. The great and resourceful area tributary to Chicago makes all this possible, and if proper statesmanship directs her energies it is rendered probable. It is simply the problem of maintaining the healthiest and cheapest city in which and from which to do business.

## TRIBUTARY BASINS AND STREAMS—GENERAL SUMMARY.

The Illinois river is formed by the junction of the Desplaines and Kankakee rivers, 9½ miles above Morris, the northern tributary heading in Wisconsin and the eastern heading in Indiana, the two enclosing the head of Lake Michigan like the branches of the letter Y. The junction is 51.3 miles from Lake Michigan by the general course of the Desplaines river and the nearest route therefrom across the land to the lake.

The following table gives the areas of the several tributary watersheds and the points at which their streams join the Illinois. These areas are computed from the county atlas maps of the State and the state maps of Wisconsin and Indiana. They include also the river front proper to the points designated. The distances are taken from the city and U. S. surveys, and are computed from the head of the Illinois. The bank is right or left going down the stream and is indicated by R. B. or L. B.

AREAS OF BASINS.

| Tributary. | Area. | Total area. | Distance miles. | Bank. | Area To. |
|---|---|---|---|---|---|
| Desplaines River | 1,392 | .......... | 00.0 | R. B. | Junction of Rivers |
| Kankakee River | 5,146 | 6,538 | 00.0 | L. B. | |
| Aux Sable River | 218 | 6.756 | 4.7 | R. B. | Morris |
| Mazon River | 540 | 7.296 | 9.7 | L. B. | " |
| Nettle Creek, etc | 63 | 7.359 | 10.0 | R. B. | Seneca |
| Waupecan Creek and Hog Run | 70 | 7,429 | 12.1 | L. B. | " |
| Kickapoo Creek | 45 | 7,474 | 22.7 | R. B. | Marseilles |
| South Kickapoo Creek | 24 | 7,498 | 23.7 | L. B. | " |
| To Mouth Fox River | 16 | 7,514 | 33.1 | R. B. | Ottawa |
| To Mouth Fox River | 15 | 7,529 | 33.1 | L. B. | " |
| Fox River | 2,700 | 10.229 | 33.1 | R. B. | " |
| Covel Creek | 100 | 10,329 | 36.4 | L. B. | Utica |
| Clark's Run | 36 | 10,365 | 42.5 | R. B. | " |
| Vermilion River | 1,317 | 11.682 | 46.2 | L. B. | Peru |
| Pecumsaugan C'k, L. Vermilion R. | 165 | 11,847 | 47.1 | R. B. | " |
| Spring Creek | 56 | 11,903 | 52.9 | R. B. | |
| Negro Creek | 34 | 11.937 | 57.3 | R. B. | |
| All Fork | 72 | 12,009 | .... | L. B. | Hennepin |
| Bureau Creek | 480 | 12,489 | 62.9 | R. B. | " |
| Coffee Creek | 24 | 12,513 | 65.8 | L. B. | |
| Clear Creek | 52 | 12.565 | 71.7 | L. B. | |
| Senachewine Creek | 77 | 12,642 | 73.8 | R. B. | Henry |
| Sandy Creek | 147 | 12,789 | 75.7 | L. B. | " |
| Crow Creek, (west) | 88 | 12,877 | 81.0 | R. B. | |
| Crow Creek (east) | 226 | 13,103 | 89.6 | L. B. | Chillicothe |
| Senachewine Creek | 132 | 13.235 | 90.4 | R. B. | " |
| Richland Creek, etc. | 198 | 13,433 | 93.8 | L. B. | Peoria |
| *West Slope* | 46 | 13.479 | .... | R. B. | " |
| Kickapoo Creek | 310 | 13,789 | 112.1 | R. B. | Pekin |
| Luck Creek | 42 | 13,831 | 114.9 | L. B. | " |
| Mackinaw River | 1,217 | 15.048 | 121.0 | L. B. | Copperas Creek Dam |
| Tamarish Creek | 55 | 15,103 | .... | R. B. | Kingston |
| Copperas Creek | 151 | 15.254 | 134.0 | R. B. | Copperas Cr'ek Dam |
| Duck Creek, etc | 110 | 15,364 | 138.1 | R. B. | Havana |
| Quiver River | 220 | 15,584 | 149.9 | L. B. | " |
| Spoon River | 1,870 | 17,454 | 151.6 | R. B. | |
| Otter and Wilson Creeks | 140 | 17,594 | 160.7 | R. B. | |
| Sangamon River | 5,670 | 23.264 | 174.1 | L. B. | Beardstown |
| Sugar Creek | 180 | 23,444 | 177.7 | R. B. | " |
| Crooked Creek | 1,385 | 24,829 | 188.3 | R. B. | LaGrange Dam |
| Indian Creek | 290 | 25,119 | 193.4 | L. B. | " " |
| McKees River | 472 | 25,591 | 205.7 | R. B. | Griggsville Landing |
| Mauvais Terres Creek | 275 | 25,866 | 209.2 | L. B. | " " |
| *West Slope* | 75 | 25,941 | .... | R. B. | Montezuma |
| Big Sandy, etc | 190 | 26,131 | 220.7 | L. B. | " |
| *West Slope* | 75 | 26,206 | .... | R. B. | Kampsville Dam |
| Apple Creek, etc | 525 | 26,731 | 235.7 | L. B. | " " |
| *West Slope* to Macoupin Creek | 45 | 26,776 | .... | R. B. | |
| Macoupin Creek | 985 | 27,761 | 248.6 | L. B. | |
| Otter Creek | 85 | 27,846 | 256.4 | L. B. | |
| *West Slope* | 40 | 27.886 | .... | R. B. | Mouth at Camden. |
| *East Slope* | 28 | 27,914 | .... | L. R. | |

It will be noticed that thirteen tributaries, each exceeding four hundred miles in area, carry 23,699 miles or 85 per cent. of the drainage, and that the direct drainage to the Illinois is small. The Illinois basin is really a series of basins rather than a homogeneous whole.

Above Peru, about 94 per cent. of the area lies in five basins. From Peru to Copperas Creek Dam, Bureau Creek and Mackinaw River carry about half the area of 3,407 miles. From Copperas Creek Dam to LaGrange Dam, Spoon River, Sangamon River and Crooked Creek add 8,925 out of 9,865 miles. Below LaGrange, three tributaries carry over 70 per cent of the area.

If the lower Illinois be divided into three nearly equal divisions, the tributary drainage to the middle division is almost exactly the same as the total watershed above Peru, and over two-thirds of that below Peru. The other two divisions receive but 17 per cent of the total watershed, and only 30 per cent of that of the lower river.

The upper third of the lower Illinois is then practically under the drainage conditions of the upper basin, while the lower third is modified by the equal central basin, which

virtually extends across the State. Aside from these two main basins, the remainder of the watershed is largely direct shore or slope drainage.

In all studies of the Illinois river proper, these characteristics must be considered, as also the influence on floods, in the lower division, of the backwater from the Mississippi river.

## THE DESPLAINES WATERSHED.

The Desplaines unites with the Kankakee just east of the west boundary of Grundy county, to form the Illinois. It drains an area of 1392 square miles, almost wholly within the counties of Will, DuPage, Cook and Lake, and in Kenosha county, Wisconsin.

The general direction of the basin is north and south, with a length of 90 miles, and a greatest width from east to west of about 25 miles. The watershed contains three characteristic or true basins,—the Desplaines proper, Salt Creek, and the DuPage river. In a strictly topograpical sense, however, the Desplaines basin does not extend farther south than the great boundary ridge of the lake basin, which crosses the old outlet in the vicinity of Willow Springs, or this basin is within the rim of the lake watershed. Normally, therefore, the drainage south of Willow Springs pertains to the outer slope of the main ridge, and to this class belong the considerable areas drained by Hickory and and Jackson creeks. The Salt Creek basin normally extends southward nearly to Willow Springs, between the ridges now drained to Flag Creek, but the stream broke through a gap north of Western Springs, and now crosses the slope of the Desplaines basin to Riverside.

Considering the manner in which the surface configuration of this portion of the State has been formed,—a series of troughs left between morainic ridges by the retreating glacier,—the topography is better understood. The several minor watersheds would then be depressions between the ridges, gradually closing, running out to the northward in a general flat ridge, as the theory indicates. Thus, there is the ridge which limits the Desplaines watershed at Dresden, opposite the mouth of the Kankakee, extending northward and uniting with the main ridge to enclose the DuPage watershed, a second ridge uniting northward and defining the Salt Creek watershed, and finally, the eastern ridge of the Desplaines watershed, which, however, does not close upon the headwaters of the Desplaines, a summit slough draining northward, as well as southward, to Root river, which empties into Lake Michigan at Racine.

This general series of ridges closing or uniting northward is characteristic, and is illustrated in the divisions of the headwaters of the Chicago river and in the lake ridge now undergoing erosion, from Winnetka northward, uniting with the east ridge of the Desplaines watershed west of Waukegan.

All these ridges terminate to the south, are virtually cut across by the old outlet channel which drained these troughs and the glacial waters, afterward the three upper lakes from the bay which covered the site of Chicago, down what is now called the Desplaines valley below Summit.

The mother rock underlying the whole of the Desplaines watershed, except its extreme lower end, is the Niagara limestone. The Cincinnati group extends up the Desplaines and DuPage rivers five or six miles from the mouth. The watershed is then underlaid with impermeable rock, except a very limited portion of the southern end which carries some water, the Cincinnati group and possibly the lower strata of the Niagara, if of the same horizon as the rock underlying the clay beneath Chicago from which considerable supplies are obtained.

These ridges and intermediate deposits overly the rock from 20 to 100 feet in thickness, and, as was to be expected, are in the main unstratified as they were left by the retreating glacier, though a greater tendency to stratification is exhibited as the streams in the lowest levels are approached. As the great main channel is approached, the tendency to stratificaiion is more pronounced; beach, terrace and gravel deposits occur, the latter behind gaps in the ridges, as at Plainfield, where the escaping waters left only the heavier material. As a whole, however, the portion of the Desplaines watershed which

contains formations which will absorb any considerable proportion of the rainfall and deliver it equably to the streams as ground water, is very limited and confined for the most part to the lower end of the watershed.

The action of the original forces would leave the surface of the slopes in folds or rolls, the tops of the ridges in knobs and depressions, the bottom of the trough, the present stream, nearest to the eastern or innermost ridge. These depressions, these hollows, would drain into each other through the lowest lines, or the sloughs, build up, through vegetable growth and sedimentary deposition, into flat praries, while the rolls and knobs would leach out, become more friable, marly, and, together with any superficial deposits of sand or gravel, become the sites of groves and belts of timber. The farther north, the ridges closing on each other, becoming broader and flatter, the more characteristic this development, the larger depressions producing great bogs, swamps and lakes. In time, as the sloughs cut down, prairies would become dry.

This whole conception is fully borne out upon the Desplaines watershed,—dry prairies, prairies still wet, peaty bogs and swamps, small and shallow lakes becoming so, and lakes so large and deep that wave action maintains their integrity except in sheltered areas, all with more frequent belts and groves of timber northward.

This condition of things in nature makes the surface more absorbtive, and to a greater depth, and arrests the waters, delivering them more equably to the streams and maintains from the overflow of lakes and ponds and the leachings of swamps and bogs a better low water volume. The clearing away of the timber, the drainage of the wet prairies, the reclamation of bogs and swamps, removes the water faster, destroys the reservoirs of low water supply.

None of the watershed can be considered hilly or precipitous, although where the old outlet cut through the ridge, from Willow Springs to below Lemont, it has that appearance. Beyond the top of the bluffs, however, the usual characteristics of gentle undulations are observed. The lower part of the watershed was originally one-fourth to one-third timber, increasing northward to one-third to one-half the area.

The upper Desplaines valley above the Ogden-Wentworth dam, near Summit, has an area of 631 square miles and a length of 62 miles. This includes the Salt Creek valley which breaks through the dividing ridge near Fullersburg, its area above this point being 110½ miles with a length of 26 miles.*

The fall in the flood plane of the Desplaines is 90 feet in 60 miles, or at the rate of 1½ feet per mile above the Lyons dam. The fall in Salt Creek is at the rate of 3 feet per mile for 18 miles above the Fullersburg dam. From the Fullersburg dam to the Lyons dam, in the pool of which Salt Creek empties, the fall is 41.3 feet, about 8 miles by the course of the stream and 5 by direct line. The Lyons dam is 24.2 feet above Chicago datum, or low water of Lake Michigan as adopted by the canal trustees in 1847.

Both the Desplaines river and Salt Creek, in their courses through Cook county above Summit, are very direct, without any material development in crooks and bends. They have very little width of flood plane, are virtually deep groves in the prairie, and extreme high water rises nearly to the prairie level. In Lake county the Desplaines shows more uneveness in grade, with some bottoms in places, more like natural lakes drained out than a flood plane excavated by erosion. At Riverside a rock barrier is crossed with a descent of about 14 feet in three miles. A dam exists at this point, and also at Half Day, in Lake county. There is also a dam at Fullersburg, on Salt Creek.

The lower Desplaines extends from the Ogden-Wentworth dam to the junction with the Kankakee, a distance of 41.6 miles—a total fall of 105 feet at low water and about 6 feet less in flood. The area is 758 miles, of which 172 lie above Dam No. 2, at Joliet, the area draining to the canal below Summit being included.

The drainage of this portion of the valley is in the old outlet, virtually a channel of passage for thirty miles without other tributaries than the bluff drainage. In flood, a portion

*The normal valley of Salt Creek continued between the ridges down Flag Creek would give a length of 36 miles, and an area of 135 miles.

the waters flow to Lake Michigan over the present artificial divide, the Ogden-Wentworth dam, by the Ogden-Wenthwerth ditch, which was designed to drain the Mud Lake region lying between the Desplaines and Chicago rivers.

In nature, the Mud Lake divide was near Kedzie avenue, Chicago, five miles east of the Desplaines at the dam. It was overflowed in floods for a wide extent, the surplus waters going to the west and south forks of the South Branch of the Chicago river. Mud Lake itself had considerable depth and was the route followed by the early French explorers and traders, and for these reasons no doubt the Desplaines was surveyed and reserved as a navigable stream to Lyons bridge.

Probably at one time, the entire upper Desplaines, and even as far south as the rock outcrop above Lemont, drained to Lake Michigan, the same as the Calumet basin now does. The south branch of the Chicago river to Bridgeport originally had a capacity proportioned to such a condition or about the same as the Calumet from a similar area, and the bed of Mud Lake for a long distance bears every indication of having been the bed of the Desplaines. The indications in the Desplaines valley below Summit, as previously explained, are all indicative of recent occupancy by the present river.

There are many ways in which the long flat divide at Kedzie avenue could have been built up and we believe there is a tradition that the bearer was concerned in the matter. In any event, the work once initiated, natural sifting would carry it on until the waters were turned out the old pass.

At the present time, a larger proportion of the flood waters of the Desplaines escape to Lake Michigan than under former conditions, for, though the dam is supposed to be at the old level of the natural divide, it is close to the Desplaines with a comparatively free channel of escape by the Ogden-Wentworth ditch.

The channel of the lower Desplaines is abnormal, or is determined by the conditions left by the ancient channel. In the "twelve-mile level," below Summit, there is practically little grade at any stage of water and the bed is the old remnant, or slough, among the boulders and in rock pockets. Thence to Lake Joliet, no channel has been cut by the present stream farther than to denude one to three feet of superficial deposits overlying the rock. For ten miles above Lake Joliet, the descent is at the rate of eight feet per mile. Lake Joliet and Lake DuPage are long, deep and wide pools, aggregating over eight miles and without sensible fall, entirely beyond any present forces or requirements. Between them are three miles of slope and one-half mile beyond Lake DuPage, over rock, the Desplaines unites with the Kankakee to form the Illinois.

The dams across the Desplaines are as follows: Daggett's Mill, one-half mile below Lockport; Dam. No. 1, ten feet high, belonging to the State, Joliet; Dam No. 2, eight feet high, one-half mile below Dam No. 1, also belonging to the State, and Adam's Dam, six feet high and less than a half mile below No. 2. Formerly a dam existed at the foot of Lake Joliet at Treat's Island, and also one at the foot of Lake Du Page. These have long been abandoned.

The State dams form two pools, aggregating a length of one and one-quarter miles, in which the Illinois and Michigan Canal crosses the Desplaines river.

One mile below Dam No. 2, Hickory creek is tributary from the east, draining an area some 18 miles long and of 130 miles. Jackson creek enters from the east, near the mouth of the DuPage, draining an area 10 to 12 miles long and of 86 miles. Both of these streams belong to the outer slope of the rim ridge of the lake basin.

From the north, the Du Page enters four miles above the mouth, draining a basin, including Rock Creek, 40 miles long and 366 miles in area. This stream descends rapidly from Plainfield, but no detailed information is at hand. The canal crosses in a pool formed by the erection of a dam eleven feet high at Channahon, and formerly a feeder dam for the Joliet level existed above. The flow of the stream is better maintained in dry seasons than that of the Desplaines at Joliet.

The following tabular exhibit gives the distances, areas of drainage, elevations referred to Chicago datum and high water in the Desplaines river. The distances are given from the mouth of the stream and the elevations of low waters are + or — according as they are above or below Chicago datum, the low water of 1847 in Lake Michigan. High water

is in feet above low water. The areas are given to characteristic points and include that tributary to the canal below Summit; also river frontage over distance between points designated.

| Point Designated. | Distance from mouth. | Watershed. | | Elevation. | | Remarks. |
|---|---|---|---|---|---|---|
| | | Area. | Total. | Low Water. | High Water. 1881. | |
| Bowmanville Cut-off.. | 60.0 | 140 | | 33.0 | 17.0 | Near south line, Maine. |
| Riverside Dam | 43.6 | 190 | 630 | 24.2 | 5.8 | Salt Cr'k, ¾ miles above |
| Brewery Bridge | 42.6 | 3 | 633 | 11.0 | 8.3 | Navig'ble stream begins. |
| Ogden-Wentworth D.. | 41.6 | 1 | 634 | 8.0 | 7.3 | 11.7 above datum |
| Willow Springs | 35.2 | | | 8.0 | 7.1 | |
| Sag | 30.4 | | | 8.0 | 6.1 | |
| Walkers Quarry | 28.8 | 39 | 673 | 8.0 | | Rock escarpment |
| Romeo | 23.0 | | | 0.0 | | Level of lake |
| Lockport | 19.2 | 156 | 790 | —22.0 | 4.8 | Norton's Tail race |
| Dam No. 1 | | | | —42.3 | 3.75 | High water on dams. |
| Dam No. 2 | 14.6 | 16 | 806 | —52.5 | 4.9 | Low water actual |
| Adam's Dam | | 4 | 810 | —60.5 | 6.0 | |
| Hickory Creek | 13.6 | 130 | 940 | —67.5 | | Low water, 1883, taken |
| Head Lake Joliet | 12.0 | | | —77.0 | 5.0 | below Joliet. High |
| Foot Lake Joliet | 6.8 | | | —77.3 | 4.3 | water estimated |
| Jackson Creek | 4.8 | 86 | 1,026 | —87.0 | | from best informa- |
| DuPage River | 4.0 | 366 | | —88.8 | 11.8 | tion. Below Lake |
| Head Lake DuPage | 3.6 | | | —90.0 | | Joliet is backwater |
| Foot Lake DuPage | 0.6 | | | —90.3 | | from Kankakee in highwater |
| Illinois River | 0.0 | | 1.392 | —93.7 | 15.7 | Junction Kankakee. |

The first area in the table includes the proposed diversion of the floodwaters of the Desplaines as contemplate l by bill passed by the General Assémbly in 1887. The route was along the south boundary of the town of Maine, down the valley of the North Branch and to the lake from Bowmanville, across Lake View north of Ravenswood. An additional area of 60 miles of the Salt Creek basin was also included in the estimates, or a total area of 500 square miles out of 634 above Summit. This project contemplated continuing the ordinary dry weather flow southward.

The Ogden-Wentworth dam at the Desplaines is a little more than four miles from the present city limits of Chicago and some six miles from deep water in the branches of the Chicago river. It is ten miles direct to Lake Michigan at the nearest point.

There is no considerable area of true bottoms along the Desplaines below Summit. Down to Lake Joliet, the stream has not cut a natural bed, or the banks are of little hight, and the stream overflows widely for a half mile or more except on the steep slopes in the vicinity of Lockport. The State works conduct the waters through the city of Joliet. Aside from a limited area where Hickory Creek debouches there are no bottoms subject to overflow until the foot of Lake Joliet is reached, except a marshy fringe bordering the high ground on either side. In the seven miles below the lake to the Kankakee, true flood plane bottoms occur, mostly on Treat's Island and about the mouth of the DuPage. These, like all bottoms built up by overflow, are at mean extreme water and are overflowed in an occasional year. These bottoms are all within the range of backwater from the Ka kakee and are only overflowed in case of floods from that stream. The area from Lake Joliet to the Grundy county line is —— acres, of which Treat's Island contains —— acres and the DuPage bottoms —— acres.

The flood discharges in the Desplaines have been taken at Riverside and at Joliet, in some cases by actual observations, but generally from the high water marks giv ng the depth flowing over the dams. Such results, if carefully deduced, are reliable within a small percentage. The volumes are given in cubic feet per second, the usual unit of engineering measurement.

The flood which culminated at Riverside, on April 21st, 1881, is the most notable of recent years. Its volume was 13,500 cubic feet per second. Floods of nearly equal magnitude have occurred in other years, for which the notes are not at hand.

The highest flood since 1881 culminated on February 9th, 1887, with a volume of 10,324 cubic feet. It fell to 8,000 feet on the 10th, to 7,000 feet on the 11th and by the 16th had dropped to 2,000 feet, rising again on the 19th to 5 .74 feet.

Every five or six years for 50 years, there has occurred a flood upwards of 10,000 cubic feet in volume. The memoranda are not in hand at this writing.

The ordinary yearly flood as deduced from marks at the Lyons dam, is 6,000 to 7,000 cubic feet per second.

From the Fullersburg dam, on Salt Creek, the four highest floods in thirty years give results, as follows:

1876—2,860 cubic feet per second.
1881—2,760 " " " "
1886—2,612 " " " "
1887—Feb. 10—2,860 cubic feet per second.

The mean may be taken at 2,800 cubic feet. It will be noticed that if the volumes of floods were in proportion to areas of basins, the flood at Riverside corresponding to the above should be 16,000 cubic feet. This is not true, however, for reasons previously given. The rule applied in basins of similar characteristics would give 9,000 feet. This ratio may apply for rain water floods, but in case of melting snow, with difference in latitude, as in all the larger floods, the problem does not yield to analysis.

The floods in Joliet are estimated from the hight on the three dams, and the results check each other closely. The following notable floods have occurred:

1877, April 7—6,410 feet per second.
1881, April 21—6,550 " " "
1883, Feb. 16—6,370 " " "
1887, Feb. 11—5,775 " " "

The highest mark in 21 years at Dam No. 1 gives 6,550 cubic feet. The mark pointed out by Mr. Adam above Dam No. 2, to which the water has reached three times in 30 years, gives 5,860. The normal extreme flood may be taken at 6,300 cubic feet per second, occurring probably four times in thirty years.

The flood of 1887, which reached its hight on February 11, with a volume of 5,775 feet, fell to 1,460 feet on February 16, and rose to 5,385 feet on the 19th. If these volumes be compared with those for Riverside, some idea may be formed of the volume escaping to Lake Michigan through the Mud Lake region.

The volume flowing through the Ogle-Wentworth ditch, as measured at Kedzie avenue in February, 1887, was on the 10th, 7,800 cubic feet; 11th, 4,636 feet; 14th, 1,625 feet; 18th, 4,000 feet; 19th, 3,042 feet.

An ice gorge on the Desplaines on the 9th and 10th of February, affected the amount of water turned toward the lake, but it is apparent that in large floods not less than half the volume of the Desplaines passing Riverside goes to Lake Michigan. All the information obtainable also indicates that it was not materially different before the ditch was cut. The railway embankments across the Mud Lake valley have been compensated for by the gradual enlargement of the ditch, an operation which will continue in the future with an increasing discharge toward Chicago.

The present dam is 11.7 feet above Chicago datum, or 3.7 feet above low water, and 3.5 feet below high water of 1881. When the water in the Desplaines stands at the crest of the dam, the flow down the Desplaines is 800 to 1,000 feet per second, depending upon whether the water is falling or rising, or on the condition of vegetation in the "twelve-mile level." Above this volume, the proportion escaping to Chicago increases rapidly with the hight of flood, and for this reason the floods passing Joliet are more uniform in volume, one year with another, than at Riverside.

No data are in hand in regard to the flood volume from the DuPage. With this it would be possible to estimate closely the normal extreme flood from the Desplaines into the Illinois river. This probably does not much exceed 12,000 cubic feet per second.

It may be assumed thus that the normal extreme flood is, at Riverside, 12,000 feet; at Joliet 6300 feet; and at mouth of river 12,000 feet. Any flood above two-thirds these volumes would be a notable one; and probably average floods, one year with another, do not exceed this.

If the Chicago outlet were closed so as to turn all the water southward, the volume at the mouth of the river would be about 20,000 feet, upon the basis of 12,000 feet for Riverside; and at Joliet, the volume at Riverside would be increased by one-sixth.

The shape of the Desplaines basin, (long and narrow,) and the fact that it covers a considerable range in latitude, materially decreases the volume while increasing the duration. After heavy precipitation, the maximum flow will come from the immediate body of the watershed, while the flow from headwater will come in to sustain the volume and prolong the flood. In 1887 the river was falling at Riverside before the flood had culminated in Lake county. The melting snow on the northern portion of the basin will maintain the flow for several days after it has melted and run away from the southern portion. In 1881 the flood maintained its height nearly for four days, and lasted about 21 days. The ground was practically saturated when winter set in, and about one foot of water in the shape of ice and snow accumulated, and all ran out or melted during three weeks, at a temperature a little above freezing point and without material rain. The southern portion of the watershed was entirely bare before the northern snows began to melt. For this reason the flood volume held measurably constant, even toward the sources of the stream, until the snow at headwaters began to be exhausted. The conditions presented in this flood are of extraordinary occurrence only. On August 10th, 1867, a downpour of remarkable intensity and purely local to the watershed immediately north and east of Joliet, produced for a few hours an unprecedented flood, carrrying away the guard bank of the upper pool and inundating a portion of the city.

These extraordinary occurrences do not, however, extend over wide areas, and for this reason their effects are local rather than general. If they did, the results would be vastly beyond experience upon large streams. Still, to the extent that extraordinary occurrences may be in a measure simultaneous in a long period of time, is due those great effects that may occur in a generation or a century. In these matters, the law of probabilities comes in with its grand and certain averages as much as in apparent accidents and insurance.

The dry-weather flow, or low-water volume, is very small, as has already been inferred from the physical characteristics of the watershed. In 1887, Salt Creek was entirely dry at Fullersburg. The Desplaines, at Riverside, reached a minimum of 4.27 feet per second (256 feet per minute), and for five months did not exceed 1,000 feet per minute. The stream has been known to be lower than this, but has never wholly run dry.

In 1879, a discharge taken by Mr. Matthewson at Romeo, four miles above Lockport, gave a volume of 5.65 cubic feet per second (339 feet per minute). The minimum volume at Riverside would not be increased, in fact, might be diminished, in passing through "the twelve-mile level," by evaporation and vegetation, in the run to Joliet. Three hundred feet per minute may be assumed as the mean extreme low water at Riverside and at Joliet, with a volume below 1,000 feet for several months of nearly every year.

For several years, owing to leakage in and about the Ogden-Wentworth dam, no low-water flow has gone below Summit for some months of nearly every year. This was the case in 1887, and also, we believe, in 1888. The ice interests below Summit have always remedied the matter in time for the winter ice crop.

No estimates have been made of the low water below Joliet, nor of the DuPage at Channahon. The DuPage is known to sustain its flow much better than the upper Desplaines, due probably to considerable area of permeable gravel beds, and to springs from the underlying rock in the lower part of its course. The Desplaines, below Joliet, is also under similar conditions. It is presumed, however, that the low-water volume of the Desplaines, at its junction with the Kankakee, will not be increased to over 17 to 20 feet per second (1,000 to 1,200 feet per minute) for its mean extreme low-water, and that it will run under 50 feet (3,000 feet per minute) for some months of nearly every year. The minimum of twenty years will probably be less than that given.

The effect of inhabitation has already been forecast. The draining out of the wet prairies, bogs and marshes, the clearing away of surplus timber, will make the floods come quicker and of greater height, and their duration will be shortened. The flow of the stream will be less sustained or the low water period much prolonged. In prolonged dry seasons, or in a succession of such seasons, the only sources of supply will be the

lakes, as the bogs and marshes will dry out and the permeable beds to feed springs are of limited extent and readily exhausted. The minimum flow at Riverside and at Joliet, will probably reduce to one-half or two-thirds its present volume,

The flood volume reaching Joliet will probably not increase, owing to the peculiar situation at Summit, by which an increasing proportion is likely to flow to the lake in the future, if the present conditions and tendencies remain uncha ged. The flood conditions at Joliet would be the same as those above, provided the waters were prevented from reaching Lake Michigan, but this would increase flood heights at Summit by four or five feet. If the lands along "the twelve-mile level" were drained by cutting the rock escarpment at Lemont, a matter of no serious cost, the same results as to floods would o tain in Joliet.

The amount of surface washing or silt from the tilled ground will also increase, but these will not be largely carried southward beyond "the twelve-mile level" under present conditions, but will go for the most part into the Chicago river. Should, however, the changes be made as stated above, they would build up the Desplaines bottoms below Summit and ultimately fill up lake Joliet, until the prism is reduced to the requirements of an alluvial stream, a velocity in flood approaching two miles per hour in place of less than one-half mile as at present.

The remarks in regard to flood increase will also apply to the basin below Joliet. Owing to the conditions under which floods come from above, there will be no radical increase. The low water volume in this portion of the stream will be better sustained, as the permeable beds are of greater extent upon the lower watershed. The rock water will not alter materially in volume. The area of pond or lake is, however, very limited. The siting from the increased supply of detritus will reduce Lake DuPage, as already intimated, in regard to Lake Joliet.

As a whole, the floods will probably be somewhat increased at the mouth of the river, but to no considerable degree, unless the entire Desplaines is turned southward. The silts carried away will ultimately increase considerably. The minimum volume will probably not reduce beyond one-half or two-thirds the present amount. Had we records of the primitive conditions, it is likely that material changes would now be evident.

These changes are likely to reach their limit in fifty years. After that, the area in trees is likely to increase rather than diminish, the effects of drainage will have been fully developed, the ponds and lakes will not be farther reduced,—may be increased.— and the general permeability of the surface will increase with the fuller development of the country. The water supply to towns and villages from sources not now contributing will ultimately reach the streams.

All these conclusions are based on the supposition that no radical change be made in the old outlet such as restoring thereto a part of the outflow of the great lakes, and also without regard to the present contributions from the Illinois and Michigan canal.

The hydrography of the Desplaines basin has been discussed at length on account of its very important relations to any plans for the increase of flow from Lake Michigan at Chicago, and also to the economic and sanitary problems of that city and its environs.

### The Kankakee Watershed.

The Kankakee unites with the Desplaines to form the Illinois, after running for two miles in Grundy county and just west of the Will county line. It drains an area of 5,146 miles, 3,040 of which lie in the State of Indiana and the remainder in Illinois, principally in Will, Kankakee and Iroquois counties.

The general direction of the basin is east and west, with an extreme length of 216 miles and a greatest width from north to south of about 70 miles. The watershed may be considered as one basin lying between the main rim ridge of the lake and the outer ridge of the Lake Michigan glacier, these two ridges closing in Indiana in harmony with the effects of the Saginaw and Lake Erie glaciers. Although the general area is not sub-divided by well defined ridges, 2,000 square miles drains to the Iroquois, the main tributary, and some 650 miles to the Yellow river, in Indiana, also a tributary from the south. There are no other well defined tributaries from the south except Horse Creek,

an area of about 100 miles, entering the stream four miles above Wilmington. All the northern tributaries are in small watersheds of 50 to 100 miles, and are simply drains for the slope of the northern bounding ridge,

Below Momence on the Kankakee and the north line of Iroquois county on the Iroquois, the streams descend rapidly and the general slope of the country is ample for good drainage. This area is some 770 square miles, and its general characteristics are similar to the Desplaines watershed. The same may be said of some 430 miles along the slope of the northern ridge east of this district. The remainder of the watershed, nearly 4,000 miles, is flat or gently rolling and at least one-half in marsh, wet prairie or lake, the Kankakee marsh alone covering about one thousand miles as a single body of land.

The larger proportion of the basin is underlain bv the Niagara limestone, with possibly some Devonian and Carboniferous beds under the upper part of the basin in Indiana. The lower coal measures underly the headwaters of the Iroquis and it is supposed that the series of rocks adjacent to the great anticimal axis may be upturned in narrow outcrops beneath the drift in the southwest portion of Iroquois county. From Momence on the Kankakee and the county line on the Iroquis, the Iroquis and Kankakee are cut in the Niagara limestone as far as the Will county line and thence to t e mouth in the shaly calcareous beds of the Cincinnati group.

Owing to the depth of the drift, the character of the underlying rocks is not well defined over a large portion of the basin. They do not belong to groups carrying any considerable water bearing strata, although the lower courses of the Niagara and the Cincinnati group may furnish a limited supply to the lower Kankakee. The copious supply from shallow artesian wells, flowing water from the base of the drift, is supposed to come from the upturned edge of the St. Peters sandstone, unable to find an outlet through the impermeable clays of the upper drift. Tdis area is limited and in the southwest portion of Iroquois county, a region drained by Spring Creek, a considerable tributary of the Iroquois river. Doubtless as the name of this creek indicates, some of the pent up waters find their way to the surface.

Geological studies indicate above the rock edges at Momence and on the Iroquois, an old trough from Lake Michigan, several miles in width. The course of this channel is southwesterly, gradually curving westerly under the site of Bloomington and to the valleys of the Sangamon and Illinois. The surface features left by this old channel are almost obscured by the last glacial period, the channel is entirely filled and obliterated. It represents same earlier glacial track and it may have had the same relation to the valley of the Sangamon and the great central basin of the State that the last glacier had to the present Illinois.

The drift overlies the rock, generally to a depth of not less than 100 feet, its depth not being well ascertained over the upper basin. It is unmodified or arranged by flowing water in large part and to that extent is not water bearing. At the same time there are probably a larger depth of superficial deposits of a permeable character than in any other basin of the Upper Illinois watershed.

There is a larger proportion of sand and gravel beds upon the ridges and throughout the watershed. Glacial flow has more or less arranged tne deposits above the unmodified drift over a considerable proportion of the lower areas. The drainage of the retreating Saginaw glacier, and perhaps of the Lake Erie glacier also, flowed down the valleys of the Kankakee and Iroquois in a shallow bed, several miles in width, carrying all the finer clays and leaving only the heavier sands and gravels. The shores of these old streams are ridged in sand, the outlines of the present great marsh in Indiana, of the valley of the Iroquois, and these sand deposits continue down the deep cut valley below the junction, especially on the south side, well down into Grundy county.

The character of the drainage upon the northern slopes has been already alluded to. To the south it is much flatter and greatly diversified in marsh, lake and roll. This is true in a remarkable degree of the watershed of the Yellow river in Indiana, and to a less degree of the Iroquois in Indiana, and in Iroquois and Ford counties, Illinois.

The banks of streams, the ridges and the higher and more permeable areas with natural drainage have been generally wooded, especially in Indiana. Some of the sandy deposits have, however, been too barren to sustain any considerable vegetation of any kind.

The surface is ge erally covered to a good depth with soil, though, as already inferred, much of it partakes of a sandy character. The great areas of marsh are virtually prairies in process of formation, in a manner not unlike that pursued by nature in past ages.

The great marsh in Indiana demands special notice. It heads very near to the big bend in the St. Joseph river at South Bend, Indiana, and indeed the St. Joseph valley is but the general continuation to the E. N. E. of the Upper Kankakee valley. It would be a matter of no great difficulty to turn he waters of the St. Joseph across the portage and down the Kankakee, a route followed so often by the early French voyageurs. Already a portion of the marsh has been drained across the portage to the St. Joseph river.

The elevation at the summit is 145 feet above Lake Michigan. The head of the present marsh is 141 feet above the lake, or 104 feet above the dam at Momence, and the declivity is very uniformly distributed over the general length of the marsh, 82 miles, giving a grade to the valley of 1.27 per mile. The width of the marsh varies from one to twenty miles with an average of about ten miles, and its mean elevation is 90 feet above Lake Michigan. The area of lands which would be benefitted by the reclamation of the marshes as assessed by the Kankakee Valley Draining Co., was about 1,000 square miles. An official report made to the Governor of Indiana in 1882, gave the lands to be directly reclaimed at 400,000 acres or 625 square miles.

The same report gives the character of the underlying deposits. The soil proper, is a dark, sandy loam, ranging in thickness from one to five feet, underlaid by fine sand, increasing downward to coarse sand and gravel, with occasional thin clayey layers, all to a depth of eight to ten feet. No rock was encountered in any portion of the valley.

Father Stephan, who was long interested in land reclamation, gives the length of the river in Indiana at 242 miles while by the general course of the river it is but 88 miles, a development in bends of over 2½ times the general length, the average grade being about five five inches per mile. Down to Momence, the stream would be 252 miles in length, on a course of about 95 miles.

Above the Ft. Wayne railroad crossing, the stream flows through the marsh without well defined banks, and it is only after its junction with the Yellow river that it can be properly considered as a river. Above the junction, the area is 1,300 square miles, equally divided between the Kankakee and Yellow rivers. This area is about 60 per cent. of that above Momence. The small tributaries are usually lost in the marsh before reaching the main stream.

From the junction of the Yellow river to Momence, the general distance is 60 miles, and the fall 57 feet, or nearly one foot per mile. The developed length is probably about three times the general course of the stream. The stream is a clear, flowing body of water with a depth of three to five feet at low water, and with a sandy, gravelly bed,

At Momence are two dams, on opposite sides of an island, the crests three feet above the limestone outcrop in the bed of the river above. The river drops to eight feet below the crest of the dam in one-fourth mi e, and in a rock bed falls 20 feet more in 14 miles, to the junction of the Iroquois, after passing the dam at Waldren, 6½ feet high. The total area of the watershed is 2,540 square miles, of which 2,342 miles lie above Momence, and 2,212 miles in Indiana.

The Iroquois has an area of watershed of 2,000 miles. It is of steep declivity over rock for about five miles through Kankakee county, but above this the stream is of little grade and of good depth, navigable, in fact, to Watseka, the junction of Sugar Creek. Above this the stream is more broken, and comes directly from the east, the area in Indiana being 828 miles. The area at Watseka, including Sugar Creek is, roughly, 1,500 miles, or three-fourths the total watershed.

The principal tributaries below Watseka are Spring Creek and Longham's Creek, both heading in marshy areas in Ford county, and Beaver Creek, a marsh-draining stream.

The large proportion of marsh upon the Iroquois watershed has already been alluded to. No data are at hand in regard to the elevations, hight of floods and volume of water in this stream.

The lower Kankakee, at the junction of the Iroquois, is nine feet above Lake Michigan, and descends rapidly over a rock bed to its junction with the Desplaines, 93.8 feet below Lake Michigan, a total fall, in round numbers, of 103 feet in a distance of 33½ miles, or about three feet per mile. There is a precipiteus descent of some 20 feet at Altorf, and another of like amount at Wilmington. The drainage tributary is 606 square miles.

The foilowing table gives the distances from the mouth of the river and the elevations at low water, referred to Chicago datum. The data at hand are somewhat confusing, but the results are believed to be approximately correct:

| Place. | Distance. | Elevation. | Remarks. |
|---|---|---|---|
| Illinois river | 0.00 | —93.7 | Junction with Desplaines |
| County Line | 2.25 | —89.1 | East line Grundy county |
| State dam (above) | 5.25 | —67.6 | Feeder of Canal |
| Dam No. 1 (above) | 6.00 | —58.5 | Kankakee county, 12 ft. high. |
| Dam No. 2 (above) | 10.00 | —49.5 | Wilmington, 11 feet high |
| Dam No. 4 (above) | 11.50 | —37.0 | Great dam, 16 feet high |
| Foot of rapids | 21.50 | —37.0 | |
| Altorf | 22.50 | —17.0 | Dam destroyed |
| Kankakee City | 30.00 | + 1.0 | Below dam |
| " " | 30.00 | + 9.0 | Above dam |
| Mouth of Iroquois river | 33.50 | + 9.0 | In Kankakee pool |
| Waldron | 35.00 | +16.0 | Above dam, 6½ feet high |
| Momence | 47.25 | +29.0 | One-fourth mile below |
| " | 47.50 | +37.0 | Pool, above dam |
| State Line | 54.50 | +40.0 | General distance |
| Baums Bridge | 82.50 | +79.0 | " " |
| Mouth of Yellow River | 107.00 | +94.0 | " " |

The Kankakee feeder joined the canal in a course of 4¼ miles from the State dam, at an elevation of 68 feet below the Chicago datum. In conjunction therewith, the navigation company improved the river to the head of the pool created by the Great Dam above Wilmington, 21 miles from the Illinois and Michigan Canal. The company abandoned the structures some years since, except those necessary for water power in Wilmington, and Dam No. 1 has been cut down two feet. The feeder was abandoned by the Canal Commissioners in 1888, and the dam is in bad condition. Dam No. 3 at Wilmington is on the opposite side of the island from No. 2. It will be seen that the Kankakee is crossed by dams at seven points.

The general hight of the immediate banks of the stream in Indiana is not found, but in one report it is stated that a rise of eight feet will flood the marshes for several miles in width. At the State line high water is about six feet, and on the dams at Momence 0.83 feet, and immediately below two feet. Below Momence, high water is reported at ten feet, and below the mouth of the Iroquois not over eight feet, until near the mouth of the river. This no doubt varies, being less on the quick descents and more on the easier slopes. In 1887 the water rose 10 feet at Wilmington, below the lower dam, and at the mouth of the river nearly sixteen feet.

The banks of the river are stated to be fifteen feet high at Momence, growing higher as the stream is descended. At Kankakee they are stated at twenty-five feet, increasing toward the mouth to thirty-five feet. There are some limited areas of bottoms between Momence and Waldron, but practically none from Waldron to the mouth; in other words, no overflows occur on the Kankakee below Momence.

The data in regard to the flow of water in the rivers of the Kankakee watershed are very meager.

The flood volume at Momence can only be inferred from the hydraulic conditions as set forth in various reports. It is probably not far from 6000 cubic feet per second at the high water mark of an occasional year, or this may be assumed as extreme mean high water, beyond which floods will not occur once in a generation.

Considering the fact that 2342 square miles of watershed are above Momence, or 45 per cent of the total area of the Kankakee basin, this volume is remarkably small, and shows the impounding effect of the Kankakee marshes. Were all the conditions normal, the flood volume at Momence would be about 26,000 cubic feet per second.

The practical effect of the marshes is similar to that of a lake, reducing the extreme volume and prolonging the time of floods, while at the same time a considerable proportion of the waters is retained to maintain the ordinary flow ol the stream. The highest waters in the marshes occur in summer, when vegetation retards the ready discharge, though it is doubtful if this corresponds to the greatest volume carried by the stream.

At Wilmington, the flood of 1887 culminated on February 19th, with a volume over the great dam of 25.150 cubic feet per second. A rise of less hight occurred on the 11th. It was this earlier rise, in combination with the rise which culminated at Joliet on the 11th, that gave the high water at Morris on the 11th, 12th and 13th. The second rise at Morris, on the 19th, came within one foot of the first, but the flow of water from the Desplaines was less. The high water of 1887 is regarded as a remarkable one, the highest for ten years at Wilmington.

Mr. E. S. Waters, who was engineer for the Water Power Company, gives the highest water which occurred for the twelve years ending 1883. His results indicate a maximum flood of 35,000 cubic feet per second. The breaking of an ice gorge above the dam in 1883 occasioned a temporary discharge of over 100.000 cubic feet per second.

Two of the most notable floods occurred in 1851 and in 1867, the latter accompanied by an ice gorge, and referred to at Wilmington as the greatest known. Other remarkable years were 1830, '37, '44, '53, '58' '69, "76, and '81, though all these dates have not yet been verified. This would give twelve notable floods from 1830 to date, or an average of one each five years.

Some of these have doubtless exceeded 30,000 cubic feet per second, and this may be assumed as mean extreme flood volume. Probably any flood exceeding a volume of 20,000 cubic feet would be classed as a notable one.

The area of basin above Wilmington is 4,926 square miles. Were its characteristics similar to those of the Desplaines basin, the flood volume at Wilmington should exceed 47,000 cubic feet per second.

If 30,000 be assumed as mean extreme flood, these volumes would be increased about four per cent. at the mouth.

Owing to the area of the basin and its large proportion of flat ground and marsh, floods culminate slowly. At Wilmington, the floods generally take two and a half to three days to culminate after heavy general precipitation. The following extract from a letter from Mr. E. S. Waters, engineer of the Waterpower Company at Wilmington for over twelve years, and who was interested in observing such matters, covers all that need be said upon the matter at this time.

"It is difficult to give any definite answer to your inquiries for the reason that the winter and spring freshets bring the storm waters to Wilmington sooner than the summer or autumn rains. Usually, after a heavy general rain, the river begins to swell in about eight hours after a heavy downfall, the river becoming blackish roily, such water coming from the drainage valley of Horse Creek. Twelve hours after the storm, the river swells still more, retaining the same general color which is caused by waters from Rock Creek. The Upper Kankakee [probably below Momence] brings down clearer water so that the color of the freshet water is made materially lighter in color. The freshet reaches its hight in about 36 hours from commencement of rise, and the waters will then fall a few inches until the Iroquois waters again swell the river, such water making its appearance in from 36 to 40 hours, and being light yellow in color, caused by the wash of the clay banks on the Upper Iroquois."

"A heavy rain that fills the marshes of the Upper Kankakee will keep up a good supply for six weeks even in time of *extreme drought*. These marshes act as a large gathering ground, and the exit from the marshes being narrow and the stream very crooked, the water is impounded and the marsh acts as a reservoir."

It is to be inferred from this letter and also from the general conditions that the Upper Kankakee does not contribute materially to the maximum volume, but comes in later to prolong the rise.

The extreme low water at Wilmington for the twelve years preceding 1883, from data furnished by Mr. Waters, was 420 feet per second (25,200 feet per minute.) This, however, continued for less than one week. The usual low water run is given at 1 300 cubic feet per second (7 ,000 cubic feet per minute) and the common run for eight months in the year does not fall below 2,350 cubic feet per second (201,000 feet per minute.)

On September 9, 1867, a measurement was made near the mouth of the river in connection with the survey for the improvement of the Illinois river. The volume was 27,377 cubic feet per minute. The streams are said to have been lower in 1867 than for the preceding twelve years.

Two measurements were made above Momence, December 12-13. 1871, for the Kankakee Draining Company, and the volumes ascertained have been used as the ordinary flow of the stream for the purpose of computing the capacity of ditches for draining the marshes. The measurement at the State line gave 1,271 cubic feet per second (76,260 cubic feet per minute), and at Momence, 1,457 cubic feet per second (87,420 cubic feet per minute.) The flow for eight months is probably in excess of these volumes. They are not far, however, from what Mr. Waters gives as ordinary low water at Wilmington and it is known that this is maintained largely by the flow from the marshes above Momence. No data are in hand in regard to the flow from the Iroquois.

The mean extreme low water at the mouth may be taken at 30,000 cubic feet per minute. The volume has been less than this twice if not three or more times in thirty years. It is probable that the minimum will run under 76,000 cubic feet per minute for some months of nearly every year.

The effect of inhabitation will be most marked upon the flow of waters from the Kankakee basin. This tributary, more than any other, and in a degree only approached by the Fox, is the controlling factor in the regimen of the Illinois river as far as the mouth of the Sangamon. More, also, than any other will its regimen be radically changed by the reclamation of its marshy areas and the general improvements that will be made in the drainage of its lands during the next fifty years.

In a minor and desultory way, much has already been done to make apparent the tendencies. The borders of the great marshes have been narrowed, drainage districts have organized and put ditches through large areas, minor areas have been ditched by local owners and lands tiled, everywhere and constantly, the tendencies are to destroy the reservoirs which hitherto have maintained an equable flow. Already it is noticed that floods "come quicker" than formerly and the low water's volume is less sustained.

All this drainage is easiy accomplished, the only obstacle being that association of effort which has not hitherto proved practicable. The great bodies of marsh all have ample grade, the waters are impounded by the rank vegetation upon the considerable slopes, the streams are sinuous lines or sloughs, which void the water slowly; in fact, we have in the Kankakee basins great prairies in process of formation in a manner not unlike that by which prairies have formed in the past. Gradually they grow higher, imperceptibly the water is more largely confined to the line of drainage, the stream grows more defined and capacious, discharging the waters more rapidly, broad expanses, overflowed in high water, succeed, the wet p;airie stage is reached. The channel is defined, it crooks and loops about in order to keep its grade down, so that its velocity shall not exceed the limit for a stable channel. With this process, however, there comes a time when the growing capacity of the stream is greater than is consistent with stability, when the increasing velocity moves the material of the bed in a greater degree, bends erode, cut-offs occur. The equilibrium is destroyed, the stream concentrates, shortens, cuts deep into the superficial deposits until its grade is reduced to stability, or non-erodable strata or sorted stream bed arrests its further deepening. The prairie is drained, a deep drainage line, perhaps a valley, is excavated, and lateral drains or valleys are thrown out. This, in a few words, is the general process of evolution.

The Kankakee marsh is a great prairie in process of formation, on a general slope of over one foot per mile, much too great for a stable river in an alluvial channel. It is

underlaid by many feet of sand and gravel. It has a sinuous drainage line, with all the development in length possible without its bends looping into each other, and thus its grade and velocity are reduced so as to be in equilibrium with the material of its bed; thus it maintains a stable course. A few cut-offs, a shortening of the stream, will quicken its velocity, set it to eroding its bed and banks, gather in more rapidly the overflow waters, and thus, in a few years, a radical change may occur.

It is proposed to cut down the rock barrier at Momence and remove the dams. The State of Indiana is already making provision for the execution of a great main ditch, which will have three times the grade of the original stream and be much deeper, as proposed in the report of 1882.

Such a ditch will undoubtedly drain the marshes. It will do more. It will enlarge, deepen; lateral drains will cut out through the marsh until the underlying clay is reached, when the erosion will be less pronounced. Millions of yards of sand and silts will be carried down the Kankakee, will pass the heavier grades of the Illinois and stop in the lower river, where present natural forces will be inadequate to their removal. All this will occur quickly, within a few years after the main ditch is so developed as to gather the waters. The marsh will be deeply drained, and man has only to initiate the effort.

All this in a minor degree will occur in the drainage of other marshes, but none of them are so characteristic or extended in the peculiar development described.

While it may not be public policy to obstruct such operations, we must not be unmindful of the effects. It is sometimes possible to make the injury as little as consistent with the greater purposes to be accomplished.

No doubt within fifty years all the marshes will be reclaimed, the wet lands drained, the bogs, ponds and lakes reduced. The streams of the Kankakee watershed will then be subject to conditions differing radically from the present.

It will have quite a large proportion of its area permeable to a considerable depth on comparatively level surfaces. This condition will reduce floods, distribute flow in the streams and make the low water more persistent as compared to some other basin like the Desplaines for instance. At the same time it lies in a uniform latitude, so that the snows will melt over its basin more uniformly and it lies more nearly in the track of the summer storms.

It is doubtful if its flood volumes will be less in proportion. The ordinary flow will be better maintained on account of the greater proportion of permeable strata. The extreme low water volume in some years of persistent or in succeeding years of drought will be proportionally as low, as the permeable areas are of two little depths and the drains may not cut sufficiently deep to even get their full effect.

If these general ideas be applied then there may be expected ultimately a flood volume at Momence of not less than 26,000 cubic feet per second, or four times the present volume, and it will come quicker and be less prolonged. At the mouth of the river the volume will probably increase to 45,000 or 50,000 cubic feet per second, or be increased over fifty per cent beyond present extreme floods.

The low water volume at the mouth occuring in an occasional year may be less than 5000 cubic feet per minute, one-sixth of that now assumed, and it will probably be less than 10,000 cubic feet per minute in many years. The Yellow river, many years ago, in its natural condition, with its large development in lake and marsh and timber, gave a measured flow as low as 1¼ cubic feet per minute per square mile. This has since no doubt sensibly reduced. The entire watershed will doubtless give less in time.

A large proportion of these effects are likely to be brought about quickly by the wholesale draining of great marsh areas. Accompanying such operations will be an enormous increase in the supply of detritus until the drainage lines are finally established in natural equilibrium. Even then the detrital load will be multiplied over the present amount, as the increased washings from the tilled and sandy ground will no longer be impounded in the adjacent marsh, but will go to the drainage channels.

It will be seen how radically detrimental to the interests of the Illinois valley may be the complete reclamation and inhabitation of the Kankakee watershed.

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